REPORT OF A COMMITTEE

APPOINTED BY THE

PRESIDENT OF THE LOCAL GOVERNMENT BOARD

TO INQUIRE INTO THE SEVERAL

MODES OF TREATING TOWN SEWAGE.

Presented to both Houses of Parliament by Command of Her Majesty.

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EXPLANATION OF THE TERMS USED IN THIS REPORT.

SEWAGE.—The fluid refuse of a town.

SEWER.—The main conduit for sewage laid within a town.

DRAIN.—The tributary conduit for sewage from houses to sewers.

SEWERAGE.—A system of sewers.

RAW OR CRUDE SEWAGE.—Sewage as it flows untreated from a sewer.

CLARIFIED SEWAGE.— Sewage deprived of solids and flocculent matters in tanks.

PURIFIED SEWAGE.—Sewage filtered through land sufficiently to have neutralized the salts.

EXCRETA, used as a singular noun.—Fæces and urine combined.

DUST.—The ashes and other dry refuse from houses.

THE A. B. C. PROCESS.—Sewage treated with Alum, Blood, and Clay, &c.

M. AND C. PROCESS.—Initials of the patentees. The ingredients used are lime, carbon, soda, per-chloride of iron, and ashes.

THE PAIL AND GOUX SYSTEMS.—Moveable vessels placed beneath privy seats prepared to receive excreta.

LIST OF MAPS AND DETAILS OF SEWAGE-FARMS.

SEWAGE DISPOSAL.

The Maps referred to in this Report will be found in a separate cover.

INSTRUCTIONS FOR INQUIRY.

(Copy.)

Local Government Board,
Whitehall, S.W.,
June 19th, 1875.

Sir,

I am desired by the President to enclose, for your information, a copy of a minute of the Board, dated 17th instant, directing an inquiry into the practical efficiency of the chief systems of sewage disposal now in operation, and for which loans have been sanctioned by this Department.

The President considers it desirable that the proposed inquiry should be undertaken as soon as possible, and I am therefore to request that you will be good enough to make the necessary arrangements for entering upon it in conjunction with the other gentlemen nominated by him. The principal points to which it is important that your attention should be directed are fully stated in the Minute.

I am, Sir,
Your obedient servant,
(Signed) John Lambert,
Secretary.

Robert Rawlinson, Esq., C.B., C.E.
&c. &c. &c.

SEWAGE DISPOSAL.

The attention of the Board has for some time past been directed to the great difficulties experienced by sanitary authorities in devising means for the disposal of the sewage of their districts; and, having regard to the frequent applications which are made to them for advice on this subject, they have deemed it expedient that special inquiry should be made under their direction into the practical efficiency of the chief systems of sewage disposal now in operation, and for which loans have been sanctioned by them.

The systems, to which the Board refer, are those for the disposal of sewage ;

1. By sewage-farms,
2. By land-filtration,
3. By precipitation and by chemical processes:

And in order that they may obtain reliable information as to the results of each of these processes, they have determined that Mr. C. S. Read, M.P., one of their secretaries, and Mr. Rawlinson, C.B., their chief engineering inspector, in conjunction with Mr. Smith, the secretary to the late Rivers Pollution Commission, as their assistant, shall, as early as practicable, visit a limited number of localities in which the processes in question are in operation, and report fully to the Board thereon.

The points to which attention must be directed and upon which the Board are desirous of obtaining information, are mainly the following :—

1. The nature and character of the works and their actual cost; the rateable value of the district, and the population for which the works are available.
2. The length of time during which they have been in operation.
3. The effect of the works on the sanitary condition of the district, so far as it can be ascertained generally.
4. The efficiency or non-efficiency of the works as a means of disposing of the sewage of the district, and the quality of the effluent water in relation to its purification and deodorization.
5. Whether any nuisance is or has been occasioned by the works.
6. The annual outlay required for their maintenance and working, as distinguished from repayments of principal and interest, which should be shown separately.
7. In the case of sewage-farms, the acreage, description of soil, system of cultivation, the kind of crops, and the financial results.
8. In other cases the amount realized by the sale of the sewage.

The Board consider that at least four examples of each system should be included in the inquiry ; and they are desirous that the separate reports should be accompanied by a general report on the merits of the different systems.

(Signed) G. Sclater-Booth,
President.

Local Government Board,
June 17th, 1875.

TO THE RIGHT HON. GEORGE SCLATER-BOOTH, M.P.,
PRESIDENT OF THE LOCAL GOVERNMENT BOARD.

SIR,

HAVING in June 1875 received instructions to inspect examples of main sewerage outfall-works, so as to be enabled to report on the same, and to ascertain the facts as to sewage irrigation, we have visited Edinburgh, Wrexham, Chorley, Blackburn, Doncaster, Harrogate, Wolverhampton, Leamington, Warwick, Rugby, Banbury, Bedford, Croydon, Norwood, Reigate, Worthing, Aldershott, Romford, Tunbridge-Wells, Cheltenham, Merthyr-Tydfil, Barking, Norwich, and Enfield; Kendal, where the downward intermittent principle is carried out; Leeds, Bolton, Coventry, Tottenham, Edmonton, and Hertford, where sewage is treated by a chemical process; Bradford, Birmingham, and Luton, where sewage-sludge is precipitated by the addition of lime; and Halifax, Rochdale, Salford, and Manchester, where the pail system is partially used for dealing with excreta. We also visited Leyden and Amstersdam, where the pneumatic system is partially in operation; Paris, where only a portion of the sewage is utilised in irrigation; and Brussels and Berlin, where the sewage is about to be disposed of in irrigation.

We have obtained returns from the several towns visited as to their population, annual rateable value, the costs of the works connected with sewage treatment, the volume of sewage dealt with, and other details relating to the several points referred to in your instructional minute. The particulars thus obtained will be found in the following Report and Appendices 1, 2, 3, and 4.

The several Local Authorities, both at home and abroad, readily furnished such information as they had, and we required, and to them our best thanks are due.

Having examined the different modes of dealing with refuse, solid and fluid, in the several towns now reported upon, we beg to submit the following conclusions.

CONCLUSIONS.

1. That the scavenging, sewering, and cleansing of towns are necessary for comfort and health; and that, in all cases, these operations involve questions of how to remove the refuse of towns in the safest manner and at the least expense to the ratepayer.

2. That the retention for any lengthened period of refuse and excreta in privy-cesspits or in cesspools or at stables, cowsheds, slaughter-houses, or other places in the midst of towns, must be utterly condemned; and that none of the (so-called) dry-earth or pail-systems, or improved privies can be approved, other than as palliatives for cesspit-middens, because the excreta is liable to be a nuisance during the period of its retention, and a cause of nuisance in its removal; and, moreover, when removed leaves the crude-sewage, unless otherwise dealt with by filtration through land, to pollute any watercourse or river into which such sewage may flow. We have no desire, however, to condemn the dry earth or pail systems for detached houses, or for public institutions in the country, or for villages, provided the system adopted is carefully carried out.

3. That the sewering of towns and the draining of houses must be considered a prime necessity under all conditions and circumstances, so that the sub-soil water may be lowered in wet districts, and may be preserved from pollution, and that waste-water may be removed from houses without delay; and, that the surfaces and channels of streets, yards, and courts may be preserved clean.

4. That most rivers and streams are polluted by a discharge into them of crude-sewage, which practice is highly objectionable.

5. That, as far as we have been able to ascertain, none of the existing modes of treating town-sewage by deposition and by chemicals in tanks appear to effect much change beyond the separation of the solids, and the clarification of the liquid. That the treatment of sewage in this manner, however, effects a considerable improvement, and, when carried to its greatest perfection, may in some cases be accepted.

6. That, so far as our examinations extend, none of the manufactured manures made by manipulating town's refuse, with or without chemicals, pay the contingent costs of such modes of treatment; neither has any mode of dealing separately with excreta, so as to defray the cost of col-

lection and preparation by a sale of the manure, been brought under our notice.

7. That town-sewage can best and most cheaply be disposed of and purified by the process of land irrigation for agricultural purposes, where local conditions are favourable to its application, but that the chemical value of sewage is greatly reduced to the farmer by the fact that it must be disposed of day-by-day throughout the entire year, and that its volume is generally greatest when it is of the least service to the land.

8. That land irrigation is not practicable in all cases; and, therefore, other modes of dealing with sewage must be allowed.

9. That towns, situate on the sea-coast, or on tidal estuaries, may be allowed to turn sewage into the sea or estuary, below the line of low-water, provided no nuisance is caused; and, that such mode of getting rid of sewage may be allowed and justified on the score of economy.

ROBERT RAWLINSON.
CLARE SEWELL READ.

S. J. SMITH, *Assistant*,
21st July 1876.

REPORT.

A statement of facts connected with the treatment of sewage at any one town or district can only have a certain limited value, which will be in proportion to the efficiency of the system and the accuracy of the description; but any single example may not have much value outside of the special conditions of the locality. We have investigated examples of the waste of sewage into the sea, of its treatment in depositing tanks without chemicals, of its treatment in depositing tanks with a use of chemicals, of its application to land in irrigation, by gravitation, and of its application to land by pumping. We have also examined several modes of removing excreta in pails, as at Rochdale. Reports more or less in detail of the several processes are given in the Appendices Nos. 1 to 4.

Modifications in the Volume and Constituents of Sewage.

The volume and constituents of sewage are modified by :—

1. The surface contour and local rainfall;
2. The geological character of the substrata, the mode of forming the surface roads and streets, and the amount of local traffic ;
3. The volume of water-supply, the mode in which it is applied, and the volume of subsoil-water taken into the drains and sewers ;
4. The mode and efficiency of the main-sewering, house-draining, and the way in which waste-water and excreta are disposed of ;
5. The efficiency, or otherwise, of surface scavenging and sewer and drain flushing.

Steep surface gradients and roads and streets macadamized, defectively scavenged, and over which roads and streets there is an excess of quick traffic, as cabs, omnibuses, and vans, will send much detritus into the sewers. Birmingham is an example of all the above-named conditions, and consequently also an example where the solids washed down to the outlet are in excess.

The volume of water supplied and passed into sewers, with the volume of subsoil-water entering them, will, during all ordinary periods, constitute the volume of sewage to be dealt with ; and as drains and sewers usually receive a portion of the rain, there will, in wet periods, be this volume extra to provide for.

Sewers and drains which have been properly designed and well executed transmit sewage day by day as generated, so that it is fresh, and not putrid ; and in the treatment of sewage by any process it is of the utmost importance to deal with it fresh, as there will be less cost in chemicals (if such are used) and less nuisance on the surface of the land if the sewage is applied in irrigation.

In a town properly sewered and drained, well supplied with water on constant service, and wholly water-closeted, the sewage will be in the richest state, and may be dealt with at the least cost and with the greatest safety to health, either by chemicals or by irrigation over land.

In a well sewered town the character of the sewage will vary in proportion to the time of day and to the habits of the population, as it will be richest in the morning, at noon, and in the evening. From midnight to early morning, for six or eight hours, the sewers will contain little more than subsoil-water and waste from defective water-supply fittings.

Towns which are defectively sewered, and in which there are many privies and ashpits drained into the rudely-formed sewers, have sewage in its most offensive and dangerous form ; and if such sewers are defectively ventilated, there will be the greatest element of danger to health. To connect dwelling-houses with such sewers by drains, especially if the drains are not ventilated, is to incur the greatest risk of danger to health.

Towns in which the so-called dry modes of treatment, or the pail systems prevail, retain human excreta for a longer or a shorter

period, as where the pails are said to be removed and emptied each week (that is 52 emptyings each year); or as in portions of Edinburgh, where the pails are said to be removed from room tenements each day, or (excluding Sundays) 312 times in the year. The wholesomeness of this treatment must depend more upon the absolute and perfect cleansing of the tubs or pails at each removal than upon the time of retention, as foul pails will become putrid, and the leaven of putridity will be communicated to the refuse as it is deposited in the pail, or tub. The cost of collecting and replacing the pails is necessarily in proportion to the convenience for removal and the distance of the depôt. The yearly cost of collecting the pails in Rochdale and of working the contents into a solid manure is about 11*s.* 1¼*d.* per ton.

The yearly costs of manipulating the solids of sewage by mechanical and chemical means are set forth in the abstracts from the reports on Coventry, Birmingham, Bradford, Halifax, and Leeds.*

Chemists' Estimate of Town Sewage not its Value to a Farmer.

With respect to the laboratory value of town refuse and of sewage, or of the manipulated solids of sewage, we do not know of a single case where it is sold at a profit; and, as a consequence, there has been local disappointment and accumulations of several thousands of tons of manufactured manure, asserted to be worth from one to several pounds sterling per ton, which prices are not realized; consequently there are these vast heaps encumbering the premises where manipulated. In the case of town sewage, we find that its unceasing flow and the great volume of water to be disposed of day by day, detract from the undoubted manurial value which there is in it, so that sewage containing ammonia, representing a manurial value of 2*d.* per ton, has to be given away, or has to be wasted into the sea. With respect to the solid manure made from town refuse and extracted from sewage, its bulk and weight reduce its value, and, as, like sewage, the production goes on all the year round, it must be heaped up until farmers can be induced to remove it—the inducement for them to do so being a price far below the cost of production.

See Analyses, pages lxi, lxii, lxiii.

Town Scavenging.

Town refuse, both fluid and solid, must be got rid of, and the more completely and rapidly the process is effected the better will it be for the inhabitants. The cost of any process should, however, be a secondary question—always provided that due skill has been, and is used in devising the local works, and proper care has been, and is exercised in supervision and labour.

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* Note.—The tank mode of treatment costs about 150*l.* per annum for 100,000 gallons of sewage per day so treated, plus the interest on the cost of tanks and apparatus.

With respect to town scavenging, the ashes and other waste refuse will have most value when retained dry, and that town will be best served where the removal is regular, and at short intervals, by dust-carts, into which the dust is discharged direct. It is a dirty process to empty dust on to the street-surface to be shovelled up by the men after some of it may have been blown about.

Town Sewering and House Draining.

Town sewering and house draining are as ancient as civilization. Drain-tubes of earthenware have been found under the mounds of the ruins of the cities of Asia. The Romans sewered their cities and towns, and drained their temples, baths, and public buildings, and the sewage polluted the adjoining rivers.

Sanitary progress in Great Britain is recent, and the first rude sewers were more mischievous than beneficial. The earliest Norman castles were not sewered, but were sinks of filth both within and without. One of the earliest improvements was the Guarderobe turret or tower, constructed in an external wall, the floor being carried over the outer face upon corbells. This floor was dished from the sides to a central opening from which excreta could fall outwards to the base of the castle wall. Some of these Guarderobe towers were removed from Windsor Castle since 1840. About the beginning of this century waterclosets were re-invented and were introduced into better class residences, the drainage from them being to the nearest sewer or from the house to some ditch or watercourse or to a pit, or even over the surface of the ground or into the side-channel of a public road. In London and some other towns the nuisance arising from waterclosets was found to be so great that Improvement Acts were obtained in which clauses prohibiting a use of public sewers for waterclosets were inserted. The old sewers were large, rude in construction irregular in gradient, having flat bottoms and being unventilated, so that every form of refuse passed into them remained to putrify, ferment, and exhale gases of a deadly strength, and on some occasions men on entering to cleanse them fell dead. The comfort and convenience of waterclosets having been experienced parties using them did not like to give them up, and as they were not to use the sewers, they were ordered to construct absorbing cesspools into which the contents from the waterclosets were to be emptied, and cesspools were constructed within the basements, yards, and gardens of London houses by tens of thousands, some larger houses having several. In course of time an overflow from a cesspool, cesspit, or ashpit, was permitted to connect with a sewer. This is the position of things now in Birmingham, Manchester, and most of the large towns of Lancashire and Yorkshire. At Windsor Castle, so recently as 1850, there were 53 cesspools within the basement all full and overflowing. This cesspool plan is in favour and full practice in continental cities and towns, as at Paris, at Brussels at Ostend, and at many other continental towns. In Holland, the rivers and

canals are the main-sewers, as, also the main sources of water-supply for domestic purposes.

At Paris and at Brussels main intercepting-sewers have been constructed, in both of which cities as in London, the sewage flows into the rivers to their serious pollution.

In Holland the pneumatic system has been partially adopted. Frankfort on the Maine has been sewered, and the houses are being drained on the English plan. In the suburbs of Paris sewage irrigation has been partially established, and more complete works of sewage utilization are contemplated. In Brussels there is a very small trial work, and Dantzic has also been sewered on the English plan, and the sewage is applied in irrigation for agricultural purposes. See Appendix No. 5, page 73, Privy system.

Sewage varies in Quality.

There have been many hundred analyses made of town sewage, and its value is stated to be in proportion to the ammonia found in it. Samples of sewage vary from less than 2½ to upwards of 15 grains per gallon, and the chemist's value is one fourth of a penny per ton of sewage for each grain of ammonia in one gallon. The most important element in sewage is the nitrogen, in the state of ammoniacal salts; or, in combination with organic matters as nitrogenous matter. The nitrogen of ammonia is, however, immediately available to vegetation, whilst that which is combined with organic matter only becomes so gradually, through decomposition. Sewage is rich or poor in proportion to the number of waterclosets used and connected with the sewers, and the state of dilution. An extravagant use or waste of water and an excess of subsoil-water seriously increase dilution. Admission of surface-water will also tend to further dilution. But water has value when applied to land in irrigation, and there are cases where extreme dilution of the sewage is not objectionable; as where the land irrigated is highly absorbent, is of sufficient area, and is under grass. Pumping to a moderate elevation—50 feet or under—is not necessarily costly, as we see that 977,470 tons are pumped at Doncaster to a head of 52 feet at an annual working sum of about 300*l.*

Sewage difficult to deal with.

Sewage as it flows from well-constructed drains and sewers contains much flocculent matter and solid detritus, which in some cases, as at Birmingham, is separated in tanks, to the extent of 109,500 tons per annum, and which sludge is difficult to manipulate, impracticable to dry, and unsaleable. Precipitation by the use of chemicals is carried on at Leeds, Bradford, Halifax, Bolton,* and at other places, as detailed in this report. In some cases there is little or no separation, as at Aldershot and Chorley, where the sewage flows direct on to the land; and at Leamington, Warwick, Bedford, Banbury, Worthing, and Doncaster, where crude sewage is pumped and delivered by carriers over the irrigated lands.† Where

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* Note.—Appendix No. 3, pages 33 to 56.
† See Appendix 1, pages 1 to 30.

the permanent sewage-carriers are duly proportioned to the volume of sewage, and are of iron, of earthenware, of concrete, or of other solid material, there is no retention of sediment, and consequently, no permanent nuisance as is the case in the large, rude, and foul open sewage-carriers at Edinburgh.

Proportion of Sewage to Excreta by Volume and Weight.

A population of 100,000, exclusively using waterclosets and producing 2,500,000 gallons of sewage daily, may be contrasted as under, to show the relative volume and weight of the sewage, the urine, and the fæces. In a mixed population of both sexes and all ages the excreta of each person per day has been found by experiment to weigh $2\frac{1}{2}$ lbs. A gallon of sewage weighs, say, 10 lbs.; 2,500,000 gallons therefore equal 25,000,000 lbs., and the excreta of 100,000 persons equals 250,000 lbs., or the proportion is as 1 to 100. The urine of 100,000 persons weighs 234,380 lbs., and the fæces 15,620 lbs.; the solids (fæces) being by weight and volume to the sewage in the proportion of 1 to 1,600. The so-called solid portion is to the fluid or urine as 1 to 16, that is, ounces to pounds.

Where human excreta is retained within houses and towns until it is removed by hand labour, or even by special contrivances, there must be a certain amount of inconvenience experienced which will be annoying; and as there is and must be a vast amount of labour expended to remove such refuse, the process will be costly, the relative cost being set forth at page 68 of the Appendix.

In all the so-called dry processes (which are not dry) there is with the excreta a considerable volume of urine and water. This is so in the pail system, and in every form of improved privy.

The advocates of these systems declare that they are aware that town sites must be sewered and that houses must be drained, if only to remove subsoil-water, surface-water, the waste-water used by the inhabitants, and the drainage from stables and privy ashpits. This subsoil-water, surface-water, and waste-water from dwelling-houses, stables, cow-sheds, slaughter-houses, and local manufactures must be treated in the same manner as sewage, before it can be permitted to flow into streams and rivers. The excreta is, however, separated under the idea that there will be more value obtained as manure, and that there will be less pollution at the outlet of the sewers. Experience and analyses show that such conclusions are erroneous. There are in manufacturing towns many sources of pollution other than the drainage of houses, of ashpits and cesspools, of cow-sheds, of stables, and the washing of the streets' surface; and in many cases this liquid will have to be provided for in the sewers, as at Coventry, at Kendal, and at other places. Sewers ought, in fact, to receive all water polluted by ordinary processes, as analysis proves that sewage is very little less polluted by the exclusion of human fæces. The Rivers Pollution Commissioners state (pages 29 and 30, Report, Mersey and Ribble

Basins) that 12 tons of average sewage from a midden and privy town will in round numbers equal 10 tons of sewage from a waterclosetecl town in manurial value, so that the mischief, cost, and intolerable nuisance of a retention of the privy system—and this also is applicable to all so-called dry systems—only reduces the strength of the sewage by two sixths.*

Sewage not Profitable to the Extent Estimated.

In 100 tons (224,000 gallons) of sewage, having the equivalent of eight grains of ammonia to the gallon, the ingredients are estimated as having a manurial value of 17*s.* 7*d.* The suspended matter, which will subside when at rest or which chemicals will assist to precipitate, is worth 2*s.* 2½*d.*; other dissolved matter which remains in the clarified water being worth 15*s.* 4½*d.* This makes the value 2·1 penny per ton, or say 2*d.* per ton, the Royal Commission (1858 to 1865) accepting this estimate of 2*d.* per ton after a set of exhaustive experiments fully recorded in their three Reports,† came to the conclusion that a farmer having to take and dispose of sewage day-by-day all the year round would not give more than a halfpenny per ton, if even this could be afforded. An examination of the abstracts in this report will show that sewage has very generally been used in irrigation at a loss.

Although this estimate appears so favourable we find that it fails to be commercially productive in practice, and we may again repeat that no chemical or other treatment of town-sewage with which we are acquainted is a commercial success; the suspended solids may be precipitated and the sewage so far clarified by these processes, but the sewage is not purified nor does the sludge appear to be increased in value as a manure so as to command a sale sufficient to pay the costs of production.

The pail system, as practised at Rochdale and other places, does not produce a solid manure of sufficient value to repay the contingent expenses, and command a ready sale.

Sewage not to be stored in Cesspools.

Sewage should not be stored in cesspools beneath houses, or near to houses within a town, neither should it be allowed to rest stagnant in badly formed sewers, nor, indeed, in any sewers; but all waste-water and excreta should pass to the drains unperceived, and should then flow in an unceasing stream; and, if practicable, at once over and through land properly prepared for its reception and agricultural use.

Mechanical Power of Water.

Water is a purifier, a cleanser, a dissolver, and a mechanical power, and will carry along down an incline the solid ingredients

* Note.—There are recent privy arrangements to intercept urine. The game will not, however, be worth the candle.

† Note.—See Appendix No. 7.

of town sewage, with road detritus, such as grit and silt; the moving power of water being in proportion to the volume, the vertical depth, and the gradient down which the flow is directed. Flushing by volume and head artificially formed will remove detritus from sewers of low gradients where accumulation may have taken place. A velocity in the sewage of two feet six inches per second will remove any solids likely to be passed into drains and sewers.

The weight of detritus and silt moved along with and by the metropolitan sewage is not so great as in some other towns, such, for instance, as Birmingham and Leeds; because in London much of the sludge is removed from the street gulleys and much is removed from the old flat-bottomed sewers by hand labour. In the aggregate a large weight of detritus is, however, swept along to the outlets, and is discharged into the Thames at Crossness and at Barking.

General Remarks on Sewage.

The mode of utilising sewage with economy must depend upon local conditions, and a waste of sewage (which is manure) can only be justified when it would cost less to waste it *harmlessly* than to utilise it, as at Edinburgh, Liverpool, and Brighton, for instance. At Edinburgh the Craigentinny meadows afford the strongest example of pecuniary success in the rough and ready use of crude sewage to produce rank crops of grass; and at Edinburgh also, in the Water of Leith intercepting-sewer we have an example, on a greater scale, of a waste of sewage into the sea at the Black Rocks outlet. The cases must, however, be considered with all their surroundings. At the Craigentinny meadows crude sewage flows down from the older part of Edinburgh without stint or charge towards land having little value in its natural state, as it is for the most part blown sand from the adjoining estuary. This sewage is received at a point sufficiently elevated to allow of its gravitating on to the land to be irrigated. It flows into rudely formed open carriers, to the highest points of the estate, from whence it gravitates by cheaply formed sub-carriers over the land below, the effluent escaping down to the boundary line of the sewage farm, which is the sea. The land is of low value as agricultural land; the sewage is abundant, far more than is required for the area irrigated; it costs nothing to the proprietor of the land; and its use, its abuse, or its waste is under no local control; it is applied in the cheapest way, and the crops are put up to auction in one acre plots each year, the purchaser cutting and removing the grass at his own cost. The mode of irrigation is uncleanly and rude, and there is undoubtedly at times an offensive smell from the carriers, from the rudely drenched irrigated surface, and from the effluent water. During winter the sewage is allowed to flow direct into the sea.

Sewage Irrigation proved not to be injurious to Health.

There is no record of any special outbreak of disease at or near the sewage farm. The men working on the land and amongst the sewage are reported to be healthy, the men cutting the grass are healthy, and the cows fed upon the grass are also as healthy as other cows, producing wholesome milk; and with respect to tapeworm, the medical men who attend the Edinburgh hospitals do not find any exceptional excess of this disease amongst their cases; but, on the contrary, less than in other hospitals. The Craigentinny meadows were made the subject of an exhaustive inquiry by the War Department during the time that Lord Macaulay was member for Edinburgh and Parliamentary Secretary for that department. Complaints were made that the proximity of the irrigated meadows and the effluvium from them produced disease in excess amongst soldiers quartered in the neighbouring barracks. Official inquiry was made by army medical officers, who took the returns of health and mortality for 20 years back from barracks situate in different parts of Great Britain where troops similar in numbers and performing similar duties had been quartered, and these returns were tabulated, the results obtained proving that the barracks adjoining the Edinburgh sewaged meadows had the lowest sick and death rate in the list, so that the allegations against the Craigentinny meadows fell to the ground.* It must not, however, be supposed that rough and ready sewage irrigation is advocated, as the evidence should only be taken as proving that the application to land of putrid and crude sewage in the most gross form does not necessarily breed a local pestilence, though such mal-arrangements may produce an offensive nuisance which ought not to be continued. But we have no evidence that these Edinburgh meadows are a nuisance injurious to health; we are, however, satisfied that the work of irrigation may be carried on in a manner much more cleanly by a construction of settling-tanks to separate the solids and by the construction of permanent main-carriers, which could be regularly cleansed. The utilisation of sewage should, in all cases, be carried on in such manner as, in the vicinity of dwellings, to be the least offensive, although additional costs may, in some cases, be incurred to pay for more complete purification.

Money Returns from Sewage contingent on Local Conditions.

The tabulated statements now made from experiments with sewage on a great scale show that money returns are contingent upon local peculiarities and management. Where the works necessary to treat sewage are simple in their construction and the treatment is unfettered by patents, there is least loss. Purification of sewage is not, however, effected by any use of chemicals which has been brought to our notice, the result in all cases having been

* See also Appendix No. 5, pages 102, 103.

clarification only; that is, a better separation of solids and flocculent matters held in suspension; seven-eighths of the salts of sewage remaining in the clarified water, so that the pollution of a small river or watercourse would not be prevented, however perfectly the sewage may be clarified, as was proven at Leamington, Blackburn, and Cheltenham, where the salts in the clarified sewage combining with the earthy matters on the beds of the streams, fermenting gave out offensive gases sending to the surface a black and putrid scum. We have no reliable evidence that the solids extracted and made into a portable manure have any paying commercial value. At Birmingham, as will be seen by the returns, there is now no serious attempt to sell the sewage-sludge, but it is at great cost, 14*l.* 10*s.* per acre, dug into a portion of the farm-land at a rate of about one acre per week, or at a loss of about 750*l.* a year. At Leeds, Bradford, Bolton, and at Coventry thousands of tons of extracted sewage-sludge remain to cumber the works.

At Halifax and Rochdale, where the pail system is in operation and the excreta is collected by hand and mixed with house-ashes, there are also thousands of tons of the prepared manure in store, because a ready sale of it cannot be effected.

At London, about 600,000 tons per day of the richest sewage in England is poured into the River Thames; at Edinburgh, the Water of Leith sewage is wasted into the sea, and this is also the case at Liverpool, at Brighton, and at most of the large towns in England and Wales which stand upon a river-estuary, or fronting the sea, as at Swansea, at Scarborough, at Sunderland, and Newcastle-upon-Tyne, and at other places.

The Pneumatic System.

One of the most complicated and costly processes for dealing with the solid of human excreta (not with town sewage), is the system known by the name of the inventor, Capt. Liernur.

The pneumatic system has been partially introduced at Leyden, Amsterdam, and Dordrecht, where we have seen it working. These towns are flat and are intersected by canals and open watercourses. The towns are not sewered on the English plan, but have surface gutters along the margins of the footwalks into which surface water flows and the inhabitants throw their waste water and liquid household refuse. There are inhabited basements below the level of the streets and gutters—in some streets the gutter is square on section—close to the basement entrance, and covered by a lid of timber which can be raised by the householder for the purpose of discharging slop-water into the channel which communicates at short intervals with a river, canal, or watercourse, as one or the other may be available. There are also small and short surface-drains opening into the watercourses as above described.

At present the excreta in these towns passes from the house-drains into the rivers, canals, and watercourses; the ashes and vegetable refuse being collected from tubs and boxes by what we

in London term *dust carts.* The rivers, canals and watercourses bordering and intersecting the Dutch towns are made into open sewers. Waterclosets on the English plan are used to a limited extent. A modified privy is however generally arranged within the houses over a vertical shaft which drops the refuse to a drain below. In many cases chamber utensils are used. The Dutch towns are deficient in water supply, so that, almost throughout the country, water from rivers, canals, or the watercourses is used for all domestic purposes, however much tainted it may be.

The country being so flat, so intersected by rivers, canals, and watercourses, and the land and street surfaces so little above the general level of the water, has induced the municipal authorities of Holland to come to the conclusion that main-sewers and house-drains, as constructed in English towns, are impracticable; hence the resort to the pneumatic system.

Capt. Liernur acknowledges that towns should have the subsoil water lowered, that they must be sewered, that houses must be drained, and that the fluid refuse of manufactures must be provided for, but insists that human excreta must be removed by separate and costly apparatus, consisting of steam-engines, air-pumps, iron tanks, and cast-iron pipes of five inches internal diameter—none more, none less—these pipes to be jointed as if for carrying water under high pressure. These pipes are not, however, laid in level and right-line lengths, but in the form of saw teeth extended, so as to break the line of pipes vertically into long downward slopes of 1 in 250, and short upward slopes of 1 in 5, the long slope and its short upward slope forming a sort of inverted syphon, where sewage must rest and block the pipe, to be sucked upwards and forwards by the partial vacuum. The soil-pans are not much unlike English waterclosets; they are fixed beneath a seat, have a syphon bottom outlet, and are specially ventilated. These pans are fixed within buildings as waterclosets are fixed, and are used as waterclosets are used; the prime difference being that the user of the pneumatic closet has no power of emptying the pan. In some cases, where a closet is liable to be much used, the pan has been filled above the brim, and the air-suction failed to empty it. In all cases the closet is a fixed receptacle, amenable to no control by the users, but dependent for its action upon a perambulating turncock. If servants disobey rules and pour in slops or the contents of chamber utensils, and the pan is full before the time of turning on the vacuum comes round, full it must remain; and if there is overflow the nuisance must be endured. This would be found intolerable in English houses, where the perfect control of the watercloset rests with the user. Capt. Liernur proposes refinements, such as a moveable lining to his pan, that it may be cleaned, which is unnecessary in the English closet. Additions to the receptacle, in the form of a self-acting shallow pan apparatus to contain a small volume of water, is to be added; this shallow pan to hang vertically when not in use, but to rise into a horizontal position so as to form a false bottom when in use. Standing in front of the seat is to raise the pan and fill it with

water ; moving from the seat is to permit it to fall down again and discharge the contents. Our experience is that self-acting apparatus soon ceases to have any action. The excreta which is pumped to the central station is in a fluid state necessarily, and is put into barrels and sent away to the country, involving trouble, cost, and inconvenience in several forms. The manure is too rich to distribute over grass-land in very dry weather without dilution, and it is too bulky to carry long distances. It is proposed to dry it ; this process must, however, greatly reduce any remuneration to be obtained by sale. At present farmers have tried the manure, and have paid at a rate of 8*d.* per 32 gallons, or 6*s.* 8*d.* per ton ; but this price was soon abandoned, the price being reduced to 2*d.* per 32 gallons, or 1*s.* 8*d.* per ton ; and ultimately, after further trial, this arrangement ceased, as it was found to be necessary to remove the excreta daily or at other short intervals, because it was not convenient for the farmer either to store it or to use it ; and in winter, during frost, the barrels in store were frozen and burst.*

Remarks on the Pneumatic System.

Captain Liernur has been particularly fortunate in having the manure which his system produces tried in Holland, as the use, application, and storage of liquid-manure is much better understood there than in England. A considerable number of the farmers in Holland grow no straw, consequently, the manure made by the cattle in winter has to be utilized in a liquid state. In England this liquid-manure is generally absorbed by the straw, or by other bedding upon which the cattle stand. Some 20 years ago there was a general movement amongst English farmers for applying the drainage from farm-yards to the land, and tanks, pumps, and liquid-manure carts were, for a time, in great request ; but the application of this farm-sewage produced so little result in proportion to the cost, that pumps and carts for this purpose are now seldom used upon arable farms. We are confident that the liquid which is collected at such cost in barrels would find no ready sale in England, even at a very low price, and we further believe that any English farmer agreeing to take it continuously from any town would not only not pay anything for it, but would certainly charge something considerable for his trouble and for the expence of removal.

If the towns of Holland, or portions of such towns, by reason of peculiarities of site and climate, cannot be sewered on English principles, and if the pneumatic system is as cheap as any of the moveable pail systems, it may be the best under such conditions for Holland, because if worked in accordance with the rules laid down the excreta will be removed daily without the intervention, trouble, and dirt involved in the pail system. The pneumatic system only deals, however, with a small fraction of the refuse to be removed from houses leaving all other forms of refuse to be dealt with in the ordinary way, so that Dutch town-sewage must flow into the rivers and canals as now, to pollute the water-supply ; or,

* Note.—See Appendix No. 4, pages 61 to 70.

some complicated mode of intercepting it must be provided at an additional cost to the local authorities.

The pneumatic system is ingenious, but it is complicated in its construction and working arrangements; and, consequently it is liable to derangements which are sometimes difficult to mend. We do not know one English town in which the apparatus if adopted would be other than a costly toy.

As may be imagined, when the nature of the arrangements and complications are considered, the pneumatic apparatus gets out of order, the slightest crack in any pipe or pipe-joint will reduce the force of the partial vacuum, and even where all the apparatus remains sound the closet-pans may not be emptied; and, in fact, neither the pipes nor the pans ever are entirely emptied. The power of air and water to remove solids through pipes being as their relative weights and velocity, and air is to water, by weight, about as 800 to 1.

Town Sewage: Its Treatment and Characteristics.

Town sewage is water holding in solution and having in suspension certain ingredients which render the water objectionable to the senses of sight and smell and unfit for domestic purposes.

The volume of sewage in any town is in proportion to the water used and expended for domestic and manufacturing purposes, with subsoil-water and occasional dilution by rain.

Where waterclosets are in general use human excreta is added; but though this in itself is rich in manurial ingredients and is also liable to become highly polluting, it must ever be a small fraction of the whole volume of sewage—about one hundredth.

In the manufacturing districts sewage is largely mixed with the waste ingredients used. Skinners, tanners, dyers, bleachers, brewers, brassfounders, tinplate makers, japanners, wool and woollen goods washing and scouring, chemical works, and paper works, with other forms of manufactures, pollute large volumes of water, to the extent of entire rivers, as in the Aire and Calder in the West Riding of Yorkshire, and in the Mersey and Ribble basins of Lancashire. In the 6th Report of the Rivers Pollution Commission, 1874; a map shows the several localities.

All chemical treatment of sewage, by patented processes or otherwise, aims at deodorisation; that is, at clarification and purification. The processes are reported to take from sewage turbidity, colour, and scent; but no such process has ever restored sewage water to its original purity, though most of the suspended solids may have been removed, the salts of sewage remain, and generally some of the chemicals, mixed with the water.

The sewage of a town, in which there are no manufactures or dyeworks, is a turbid liquid, bluish grey in colour, having the scent of stale cabbage water rather than of human excrement; in warm weather stagnant sewage becomes offensive, having the stench of rotten eggs; when allowed to stand exposed it does not become clear, but ferments, and if confined in sewers or covered

tanks becomes dangerous to human health, though not to such an extent as the offensiveness may be taken to indicate. When at its worst, on being brought into the open air, men work amongst it without any apparent injury to their health. The only safe way to utilize sewage is, however, by a daily application of it to land whilst it is comparatively fresh, as at Bedford, Aldershot, Carlisle, Doncaster, Chorley in Lancashire, Leamington, Rugby, and other places where sewage irrigation has been established and the sewers transmit in a continuous stream the daily volume.

Receiving sewage in tanks to abstract the solids will add to the impurity and offensiveness of the fluid if there is any lengthened retention, or if the tanks are not rigidly cleansed at short intervals, so as to remove any of the leaven of putridity from the surfaces. All sewage-tanks should be simple in form and construction, the material should be either of a vitreous character on the surfaces, such as glazed bricks, or of Portland concrete; no sewage-tank should be arched or vaulted over. There may be an open-sided shed louvered at the ridge, and the area of land occupied by both yard and tanks should be fenced in.

The sludge separated from sewage contains from 80 to 90 per cent. of water, and if deposited on the surface in this state it will not dry in any reasonable length of time, but will skin over and remain wet. Artificial drying is not practicable on account of the cost. Mixing with dry ashes and street-sweepings appears to answer best.

Unventilated Foul Sewers and Sewage Tanks dangerous.

Foul sewers and foul vaulted sewage-tanks, if unventilated, will contain carbonic acid gas, and will give off sulphuretted hydrogen, both of these gases being generated from decaying vegetable and animal matters. A complete and perfect disinfection of sewage and sewage deposit by the addition of any known materials, solid or fluid, would be so costly as to be impracticable, and the materials so disinfected would have no equivalent increase in commercial value. To completely disinfect one cubic foot of sewage-sludge and excreta would cost, in the materials, about 1*s.* or 27*s.* per ton.*

Carelessly Cleansing Sewers during Periods of Sickness dangerous.

Cleansing the putrid refuse from unventilated sewers or from covered tanks is a dangerous process, men having fallen dead during the operation. A sewer or tank full of refuse is dangerous, but when first emptied, and for some time after, there may be the greatest danger, as the sides and bottom are coated with putrid leaven and the increased cubic space within is filled by highly concentrated gases and effluvium, consisting partly of floating particles suspended in the air. When there are foul sewers and cesspools where disease, such as typhus or typhoid, breaks out, it is then most dangerous to attempt cleansing unless the sick are first removed and the greatest precautions in disinfecting are taken.

* Note.—See Appendix No. 5, page 77.

Details of the Modes of dealing with Sewage.

The application of town sewage to land is shown in this report to be the cheapest mode of disposing of it. The first cost of purchasing land for a sewage farm, of preparing this land to receive and filter sewage, and of constructing the necessary works and machinery, may require a rate in aid during the term allowed for repayment of the capital; but in most cases; where the sewage can be applied at a reasonable cost, by gravitation, so far as our investigations have been extended, there will be an available income from the farm at the termination of the temporary debt.

Sewage irrigation should in all cases be practised where there is land to be obtained, and the prospect of a balance of income in its favour, as sewage-grown grass is wholesome, and when used for dairy-cow feeding produces good milk, and affords employment to a large number of labourers.

The application of sewage to land need not in any case produce a swamp, nor generate malaria, as the volume of sewage applied at any period should be delivered in a thin film, such as the land can absorb at once; that is, within a few hours of its delivery.

Sewage should not in any case drench the land to which it is applied as is usual with water irrigations, where extensive areas are laid under water for several days at a time. The volume of sewage from any town being known, the sewage-farm should be from 10 to 15 per cent. greater than the area required for one week, and no more than one tenth of the area of a sewage-farm should ever be under sewage at one time.

A wet season is not, as a rule, detrimental to a sewage-farm. In a wet season the value of sewage grown grass is, however, reduced in value because there is more difficulty in removing crops from the ground.

Rent of Land used for Sewage Irrigation excessive.

At Croydon some 515 acres of land are under irrigation, the population being about 56,000. This is at a rate of near 10 acres for each 1,000; or about one acre to 100. The land in use had an average rental of 26*s*. to 30*s*. before the Croydon Local Board of Health required it; the rent now paid averages 10*l*. per acre per annum.*

Examples of Sewage Irrigation.

Analyses of crude and purified sewage, at the places named, are given in Appendix No. 5, pages Nos. 77–102:—

Edinburgh, Craigentinny Meadows.	Banbury.
Barking, Lodge Farm.	Warwick.
Aldershot Farm.	Worthing.
Carlisle.	Norwood.
Penrith.	Croydon.
Rugby.	Woking.

* Note.—A sewage-farm will not bear a rent of 10*l*. per acre. About half this sum is as much as should be paid if the income is to cover the expenditure.

Analyses of town sewage having been so recently made for the special purpose of informing Parliament, that we did not consider it necessary to again incur the costs of special analyses being made for our Report; but we have deemed it proper to have samples of the most recent specimens of manipulated sewage-sludge analysed, and the results will be found in the Report by Dr. A. Voelcker, F.R.S., pages 40–43, and in Appendices Nos. 1, 2, 3, 4.

A sewage-farm should be so laid out and managed that a sufficient area of land shall be under sewage every day in the year, winter and summer; and as town-sewage is seldom below 40 degrees in temperature, irrigation can be carried on. And if sewage should freeze on the surface of land which is without crop no injury is done, and when thaw sets in absorption takes place.

The mode of laying out a sewage-farm cannot be fully described in this report, but see the maps and diagrams for partial elucidation. As a rule it may be stated that the works should be simple in character that they may be cheap in construction. Good examples may be seen at Doncaster, at Bedford, at Leamington, and at Aldershot.

Permanent sewage-carriers should contain the land and be laid so as to be level, the grade of the land being provided for by vertical steps regulated by stops, overflows, and wash-outs; side-junctions to be provided on the lower sides of the carriers to draw off sewage for distribution over the land. If a permanent sewage-carrier is laid with a fall, it will be impracticable to block the flow at any point and preserve an even surface, as sewage blocked in a sloping channel would flood over the point of stoppage; hence the necessity for level lines at the surface.

Tributary-carriers may be made by a plough, the cross-sectional form and the gradient being suited to the character of the soil; the larger carriers may have a grade of 1 in 400; the smaller or "herring-bone lines" may have a grade of 1 in 300. These temporary carriers will be broken up with the plough at intervals, and be renewed as required.

Crude sewage can be used under certain conditions to warp the land; that is, the sewage with all the sediment it will carry may be passed along the carriers to be incorporated with the soil by being ploughed in, and the water of sewage may in some cases be made to carry an extra weight of silt.

The solids of sewage, as also manure made on the farm at the cattle sheds, may be used on some farms with advantage, as it does not follow that liquid sewage will in all cases supply manure sufficient.

During dry seasons the whole of the water applied in irrigation of free soils is absorbed or evaporated, the drains being absolutely free from any outflow. At all periods evaporation and absorption dispose of a large percentage of the water; and if the land is deep drained and well cultivated, the outflowing water from the drains is free from colour and scent; and if passed into a water-course does not taint the bed of the stream nor produce sewage growth so offensive in sewage polluted streams.

Where the area and surface slope of a sewage farm is favourable, intercepting drains may bring the once filtered sewage to the surface and so allow of a second or a third filtration. In a dry season there will be an advantage in this arrangement. Where the land is marl or clay this mode of irrigation will be specially advantageous, as the main purpose of a sewage-farm is to act as a sewage-filter and purifier, and the more completely this filtering is performed the better will be the results.

Land may be prepared to filter sewage, as suggested by the Rivers Pollution Commissioners. (Mersey and Ribble Basins, 1st Report, pp. 60–70.) Where small areas of land are alone available this mode of purifying sewage will be advantageous. The crude sewage should have suspended solids separated in tanks that the clarified fluid may more readily filter through the least area. A good example of sewage filtering through land on a working scale may be seen at Kendal.

Area of Land required for a Sewage-Farm will depend on Local Conditions.

The area of land required for a sewage-farm will be governed in a great measure by the character of the subsoil, as if it is very porous or otherwise; as also by the volume of sewage and subsoil-water in proportion to the population. At Doncaster, with a sewage-farm of 264 acres and a population of 20,000, the average daily flow of sewage being about 600,000 gallons, 120 acres of land of a light sandy and open character have for three years absorbed the entire sewage, only about five acres at any one time being under sewage, and one acre has occasionally absorbed the entire volume of one day. At Croydon about one acre to each 100 of population has been provided. For a population of 60,000 there are about 15,000 waterclosets in use; or, one to four of the inhabitants. There are the contents of 25 waterclosets in 20 tons of sewage each day; or, about 7,000 tons of sewage per acre per annum.

Small fields enclosed by large fences will be detrimental to sewage farming; land which is open and without inner fences, having a uniform surface and gentle slope to the south, will be most advantageous. Good roads will, of course, as in any other case, be an advantage; but it will neither be desirable nor necessary to construct many roads of a permanent character through and over a sewage-farm, as the land, if well laid out and properly drained, may be carted upon to remove the crops.

Italian Rye-grass the best Crop under Sewage.

Italian-rye-grass is probably in all respects the most advantageous crop to be grown under sewage, as it absorbs the largest volume of sewage, occupies the soil so as to choke down weeds, comes early into the market in spring, continues through the summer and autumn, bearing from five to as many as seven cuttings in the year, and producing from 30 to 50 tons of wholesome grass upon each acre. The area placed under this crop must,

however, have reference to local means of consumption, as the young grass will not keep nor bear long carriage. It is most profitable for feeding milch cows. A dairy and a sewage farm should, therefore, wherever practicable, be associated. In a dry and warm summer good hay may be made, which will be sweet and wholesome.* For full details of experiments with sewage grown grass, meadow and Italian, and for analyses of the milk produced, see the Official Report, Royal Commission appointed to inquire into the best mode of distributing the sewage of towns and applying it to beneficial and profitable uses. See also Appendix No. 7.

A Portion of a Sewage-farm should be deep drained to act as a Land-filter.

A portion of each farm should be specially deep-drained and prepared for land-filtering the sewage during winter or wet weather. When these filters are laid out in raised beds, some roots and vegetables can be cultivated with success, as the sewage generally flows down the channels. But in times of flood and storms the sewage may rise above the beds, so that it appears *oziers*, which would not be damaged by being flooded for days, may be the safest and therefore the most profitable crops to grow upon them.

Experience has proved that each day's sewage may be disposed of throughout the year so as not to cause any nuisance. Land well drained, properly laid out and managed, does not swamp at the surface, neither does it choke in the subsoil, as in fallow-land oxydation goes on betwixt the intervals of irrigation, and at any time the few grains of matter extracted from the sewage-waters are only a homœopathic dose to the land compared with the bulk of soil, six feet in depth. It is a few grains of salt and organic matter extracted from the sewage which remain for the use of the plants, the water evaporating or flowing from the drains. In dry seasons, for weeks at a time, the drains deliver very little water.

Drains and Waterclosets.

Drains must not traverse the basements of houses, but must commence at an outside wall and be fully ventilated. Water-closets must not be within the body of a house, but against an external wall, the soil-pipe being ventilated above the roof, with an open top, so as to ventilate fully, the watercloset room having full and free ventilation at the ceiling. The main sewers must be true in line, having smooth and even gradients, and be fully ventilated. The water supply must be constant and abundant, laid on to each house and to each watercloset; contamination by sewage gas within dwelling-houses will then be practically impossible.

Sewage is the waste-water from towns and the polluted water and liquids from manufactures. Where the privy, cesspit, and cesspool are retained the corrupted fluids from these pass into the

* Note.—July 1876. On the Doncaster sewage-farm 18 acres of Italian rye-grass have been cut (about 9 tons green) and made into hay (about $2\frac{1}{2}$ tons per acre), or some 45 tons of hay from one cutting alone.

sewers. Where waterclosets are used drains and sewers remove the contents at once.

Sewage is injurious in proportion to its age and putridity. Fresh sewage, if removed day by day, does not, in that time, become putrid; and, consequently, is not so injurious to health as putrid sewage is.

In towns completely sewered and drained, and fully supplied with water and waterclosets, there is an unceasing flow along the sewers to the outlet, and the strength of the sewage varies during the day in proportion to the use of water and of waterclosets. The flow is greatest in the morning, at noon, and in the evening. At night the sewers deliver almost pure water, consisting of waste from leaking pipes and taps, with subsoil water.

Where waterclosets are in full use, as in London (about 700,000), in Croydon (15,000), in Leamington (about 8,370), in Harrogate (about 1,620), in Cheltenham (about 8,500), and in like proportion in some other towns, the entire of the polluted fluids, with the effete matter of the watercloset, passes at once to the common outlet. The London sewage is at present wasted into the river Thames; but at Croydon, Leamington, Harrogate, and Cheltenham the sewage is purified by irrigation, in each case producing useful crops of grass and vegetables.

Where towns are situate on the sea or on the estuaries of tidal rivers sewage is wasted, as at Brighton, at Liverpool, at Sunderland, and even at Edinburgh, where the Water of Leith intercepting sewer discharges the sewage from a population of about 100,000 by a cast-iron outlet direct into the Frith of Forth. When sewage shall be wasted in preference to utilising it, must depend upon local conditions. The waste of sewage must not, however, produce a nuisance injurious to health, and this wasting of it certainly ought to be cheaper than using it under any of the precipitating and chemical or irrigating processes at present known.

Clarification of Sewage.

Clarification by deposition in tanks and treatment by chemicals remove detritus and suspended matters from sewage, but, as explained, will not fully purify the fluid. This removal of the solids will, however, be an advantage, as a vast mass of matter liable to choke the bed and banks of a stream or river will be removed, which, when allowed to accumulate, becomes putrid and offensive. The streams in Lancashire and Yorkshire are so fully occupied, and water is of such importance, that the manufacturers must have it, though dirty; steam-boilers being specially constructed to enable steam to be generated from dirty water. The cost of treating sewage in tanks and by chemicals appears to be about 1,500*l.* per annum for each 1,000,000, or 150*l.* for each 100,000 gallons per day. The cost is therefore in round numbers about $\frac{3}{4}$ths of a farthing per ton of the sewage so treated. Any income realised by the sale of the extracted and treated sludge will be in diminution of this cost.

The gross cost of purifying sewage by irrigation is, per ton, at Doncaster $\frac{23}{64}$ of a penny, at Bedford $\frac{51}{64}$ of a penny, at Leamington $\frac{38}{64}$ of a penny, at Cheltenham $\frac{19}{64}$ of a penny, and at Banbury $\frac{48}{64}$ of a penny. These farms may be accepted as fair samples of thus utilising sewage.

The use of sewage in agriculture is comparatively new, and the best mode has not in all cases been practised. We, however, indicate Aldershot, Bedford, Doncaster, Leamington, Wolverhampton, and Wrexham as good examples. At Lemington Lord Warwick leases the sewage to be used upon a portion of his estate, and at Aldershot, Wrexham, and at Doncaster the sewage and the land are leased, and are worked independently by gentlemen of intelligence, who make such experiments as they think proper and vary their modes of culture as best suits the sewage, the land, and the crops to be grown, There is also the incentive to make the most of the land, which is not always the case where a farm is managed through the intervention of a committee ; we therefore look for a fuller development of sewage farming in this direction; namely, letting both sewage and land on favourable terms, under restrictions to purify the sewage and cause no nuisance.

Examples of tank precipitation and chemical treatment at Birmingham, Bradford, Coventry, and Leeds, and of the pail system at Rochdale, Halifax, and at other places are described in this Report, Appendix No. 3, pages 52–59. The pneumatic system is described by the authorities of Amsterdam, Appendix No. 4, pages 62–66.

The attempts to economise in town scavenging and sewering by removing human excreta separately has been a failure ; by the dry-earth system, the Goux system, the Rochdale pail system, or by any other of the patented systems, so far as are known to us; the local costs have been largely increased, and the local nuisances also, in proportion to the time of retention of the excreta before removal ; there is also the inconvenience suffered by trespass on the privacy of the household.

Details as to Irrigation by Town Sewage.

As we recommend the application of town sewage to land, we at the same time wish to guard against some extravagant expectations of the agricultural benefits it will confer, which are held and advocated by a few zealous and enthusiastic theorists.

The continuous application of town sewage to all soils is by no means an unalloyed benefit; as in some cases and seasons, and especially upon clay-land, it may be rather injurious than otherwise. Very few crops are actually benefited by the direct application of sewage upon a stiff and retentive soil ; indeed, Italian rye-grass, cabbage, and mangold-wurtzel, seem to be the only farm crops that persistently flourish upon any soils, heavy or light, under continual doses of town sewage.

No growing crop, save natural grass, should be sewaged during

the depth of winter; and for potatoes, turnips, most vegetables, and certainly for all pulse and cereals, the land ought rather to be enriched by frequent irrigation in the preceding season, than treated with sewage when these crops are growing; except in times of great drought, and even then care is requisite. A very limited experience soon teaches us that the purification of a constant flow of sewage, and which is frequently greatest when least wanted on the farm must bring certain difficulties in its train. The cultivation of sewaged land, for instance, requires more than double the amount of manual labour which is usually employed upon arable land, and more horses must be kept than upon an ordinary farm. The amount of capital, even where the produce is sold off as soon as grown, must be greatly in excess of that required for the general ordinary cultivation of the soil; while to properly stock and work a sewage-farm upon which the main produce is consumed, quite five times the usual amount of money will be needed. One of the greatest difficulties is to keep the sewaged land clean, as not only does every seed and the minutest portion of a root-weed grow, but sewage itself often contains the seeds of numerous weeds which have been washed down from the fodder and straw of stables and cowhouses in towns.

There can be no doubt now, after the experience of some years, that the land best adapted for sewage irrigation is a warm friable loam. The only instance in which town sewage irrigation is a decided financial success is that of the Craigentinny Meadows, at Edinburgh. These meadows are, however, in reality for the most part only a deposit of sea sand, washed and blown from the adjoining estuary, and the main produce grown is nothing more nor less than luxuriant couch-grass. The enormous amount of coarse forage which is produced from such a naturally sterile soil shows the fertilizing properties of town-sewage, and also points still more distinctly to the fact that a sewage-farm should consist of land through which the sewage can readily filter. It is strange that although deluges of crude town-sewage have been poured upon portions of these Craigentinny Meadows for 200 years, the discoloration of the sandy soil only extends a few inches below the surface, and that at the depth of a foot the sand appears as bright and clean as that upon the adjoining sea shore.

It has been contended that if more land is allowed for a given volume of sewage, clay soils, when properly drained, will be equally adapted for town sewage irrigation. No doubt, if similar volumes of sewage are filtered slowly through a large area of well-drained clay, and quickly through a small area of sand or gravel, a more thorough absorption of the manurial elements from the sewage will be made by the clay than by the porous soils. But clay lands are naturally cold, they dislike wet, and will be at the best only poor filter-beds; and when sodden with rain-water the added sewage is apt to pond on the surface rather than to soak gradually into the already heavily wetted soil. After heavy dressings of sewage in parching weather

the surface of clay lands may be so baked and case-hardened as considerably to retard the growth of any plant; and if there is no crop upon the ground the land becomes solidified, and may then be seen coated with a nasty greasy film that is almost impervious to water; or, at other times, the clay cracks so that the crude-sewage passes in small streams directly into the under drains without being even clarified.

This brings us to consider the various methods of underdraining as practised at different sewage-farms we have inspected. In one instance we found that common farm underdrains which had been laid in a retentive soil were being taken up, as the crude sewage too readily found access to them, and flowed out unpurified. Upon another sewage-farm some stiff clay land which had been recently drained 6 feet deep was so cracked by heat and drought, that the sewage flowed from the surface into the drains without effecting any practical irrigation; and, although intercepted and brought to the top again, the sewage as rapidly disappeared, and at the land drains outlet the effluent was hardly distinguishable in colour and smell from that of the sewage when first applied to the land.

There seems no doubt that even the lightest soils should have a few deep underdrains, as at Doncaster, and Heathcote farm, Warwick, so as to prevent the sewage-water from lodging in the subsoil. All land of medium staple should be thoroughly under-drained, and clays require the drains to be multiplied, so that the interval between them shall not be more than 15 feet; and care should be taken that the drains are so formed that no sewage-water can flow vertically into them. To prevent this, upon the top of the drain-pipes, a foot of the most retentive portion of the soil should be damped or puddled, and tightly rammed down, so that the sewage-water after percolating through the subsoil shall flow horizontally into the drains, and not rush into the drain-pipes through the loose mould or cracked clay directly from the surface.

As already observed, the chief produce of a large sewage-farm, which is to earn the most money, must be Italian rye-grass; because it is a plant which luxuriates in moisture, and feeds with singular avidity upon all kinds of liquid-manure: and the quantity of such liquid-manure given need only be limited by the means at hand for its ready disposal. But the demand for cut grass is so variable, that this is not a very easy task. Rye-grass, even when heavily sewaged, grows most rapidly in wet weather: consequently when there is much rain, a greater crop is produced, when it is most difficult to deal with; and, as there is at such times a more plentiful supply of similar green food on other farms in the district, the demand for the rye-grass of the sewage-farm is not so extensive. In a damp season it is next to impossible to make sewage-grown grass into hay, as the soil is sodden with rain-water and sewage, and the young undergrowth of grass so soon springs up that the land must be cleared of the cut grass to enable the next crop to grow; and any removal of the cut grass

to other ground for the purpose of making hay, even if a suitable site is conveniently situated, will be very costly. It therefore appears to us that upon an extensive sewage-farm, where a constant demand for all the rye-grass grown cannot be depended on, a machine for making hay by artificial means should be provided.

Drying heavy crops of sewage-grown grass by artificial heat must; however, be a slow, costly, and tiresome process, and should never be resorted to unless necessity compelled this form of dealing with it, and when it appears to be the only way to prevent the total loss of the crop during continuous wet weather. We believe the best machine for the purpose is one which is the invention of Mr. W. A. Gibbs, of Gilwell Park, Essex, to whom the gold medal of the Society of Arts was awarded a few years ago for the ingenious apparatus which bears his name.

The length of time which a plant of irrigated Italian rye-grass lasts varies considerably. On some farms it has been ploughed up after one year's cropping. On other farms the practice has been to keep it down so long as there is a good plant, and it can be kept free from weeds. By fresh seed being sown among the old plants, Italian rye-grass thus treated, has lasted seven or eight years. Its more usual duration is, however, from two to three years, and as there seems to be a common belief that this plant can only produce a certain weight of grass, it may follow that the quicker the growth the more readily the plant will be exhausted.

It was a matter of pleasure and some surprise to us to find how town sewage benefited two such distinctly different forage plants as Italian rye-grass and lucerne. The latter, it is well known, grows with one deep tap-root, while the rye-grass has a dense mass of fibrous rootlets, which extend upon and over the surface of the land. At Paris the favourite green crop for sewage appeared to be lucerne, which at the time of our inspection seemed to flourish remarkably well under sewage irrigation, and to produce heavy crops of the most valuable provender. The gravelly soil and the warm climate of the district no doubt are particularly adapted for sewage irrigation, and this may be the reason why a direct application of sewage to the growth of vegetables seems to answer better than with us. The culture of Italian rye-grass has only recently been introduced on the Paris sewage-farm, but its success is so marked that it may possibly take the place of lucerne as the staple green crop.

English farmers have by some been considered over cautious in not embarking their capital in the costly cultivation of sewage-farms, but on our inspection of the Paris farms it appeared much more strange to us that so many French cultivators, whose little patches of land intersect the Paris sewage-farm, had not all availed themselves of the *free use* of the sewage. Many, no doubt, have done so, but it was difficult to comprehend how some of the farmers preferred to grow their miserably small crops when the adjoining

land upon which the sewage flowed was producing the most abundant yield.

It may be quite true that town sewage contains all the manure that most plants require, but as these elements of fertility are dispersed through a volume of water many times greater than any crop can absorb, and certainly much larger than it naturally requires, it follows that the manure is not presented to the plant in the most acceptable form. We have been also assured by a gentleman of vast experience that the long continued application of sewage to the same land fails to produce the like beneficial effect as when it was first used. It, therefore, appears most desirable that the application of sewage should occasionally be supplemented with some solid manure. Cows are the most suitable and best paying animals for consuming the produce and manufacturing manure upon a sewage-farm, and cows should always form the chief portion of its live stock. The successful management of animals, and the proper cultivation of crops under ordinary circumstances, require a fair amount of intelligence and experience; but successfully to carry out all the details of these matters upon a sewage-farm, where there is so little to guide the practical farmer, and so much to confound his past experience and upset his previous calculations, is indeed a hard task. And as most sewage-farms are at present under the control of ever-changing town councils and local boards whose members must as a rule be ignorant of practical agriculture, and whose theories upon the subject may be wild and visionary—is it surprising that such poor returns have hitherto resulted from the application of town-sewage to the growth of crops?

Disappointment has therefore been expressed at the poor financial results of sewage-farms. Agriculture is never a specially lucrative business, and during the last few years it is probable that strictly accurate accounts would prove that very little profit has been derived from the ordinary cultivation of arable land. Farms to which town-sewage is applied have invariably many unfavourable circumstances to contend with. The rent, except where the local authority has land of its own, is certain to be extravagant; the application of sewage is often too costly; the management is frequently changeable and faulty, and the prejudice against the produce of the farm is, in some districts, obstinate and widespread. But where a fair rent is charged for suitable land, the sewage is cheaply and regularly delivered, and a good market is close at hand, there is no reason to doubt that the return for capital judiciously expended upon sewage-farms will produce a higher rate of interest than the money invested by the majority of the tillage farmers throughout the country.

ABSTRACTS

From separate Reports. See Appendices Nos. 1, 2, 3.

The relative costs of sewage irrigation, where the sewage gravitates to the farms, are shown in the abstracts from the reports on Edinburgh, Blackburn, Cheltenham, Chorley (Lancashire), Harrogate, Merthyr-Tydfil, Tunbridge-Wells, Rugby, Wolverhampton, West Derby, and Wrexham. The relative cost of sewage irrigation, where sewage is pumped, is shown in abstracts from reports on Banbury, Bedford, Doncaster, Leamington, and Warwick, whilst the cost of land filtration and irrigation is shown as practised at Kendal, and the cost of the precipitating chemical and mechanical processes are shown in the abstracts from the reports on Kendal, Birmingham, Bolton, Bradford, Coventry, Leeds, Halifax, and Rochdale.

The abstracts contain statistics to which attention should be given. The returns are not however perfect, as the local works are not yet complete, and we could not, in all cases, obtain accurate returns of the costs of scavenging; the weight of refuse removed; or, the cost of removal:—

COST OF DEALING WITH SEWAGE BY IRRIGATION.

Banbury.

Population (about) - - - - -	12,000
Rateable value - - - -	£34,104
Houses - - - - - -	3,485
Waterclosets - - - - - -	2,485

Expenses incurred to dispose of the Sewage.

Outlet works, tanks, and pumping main - -	£5,500

The Yearly Cost of disposing of the Sewage.

Capital 5,500*l.* at 6* per cent. to repay principal and interest. Yearly instalment - - - -	£330
Cost of pumping sewage, including rent and working expenses of farm - - - - -	1,281
	1,611
Less produce of farm - - - -	1,451
	£160

The mean daily flow of the sewage is about 320,000 gallons = 1,429 tons, or 521,585 tons yearly. The annual cost to the Local Board in disposing of the sewage is 1,611*l.*, or at the rate of $\frac{48}{64}$ths of a penny per ton; they

* Money is advanced by the Public Works Loan Commissioners at 3½ per cent., which, to be repaid in 30 years, amounts to 5*l.* 8*s.* 9*d.* per cent. Six per cent. is however here used for the sake of uniformity and the purpose of comparison to cover incidentals and depreciation.

Local Boards do not necessarily borrow from the Public Works Loan Commissioners, neither do they, in all cases, repay the debt in 30 years, as the Local Government Act, 1875, provides for a term not exceeding 60 years, and this lengthened term, when accepted, will lower the rate of interest, but the cost of maintenance cannot be ascertained with accuracy.

receive for the produce 1,451*l.*, an amount equal to $\frac{44}{64}$ths of a penny per ton of sewage, and consequently lose 160*l.*, or about $\frac{4}{64}$ths of a penny per ton, or at the rate of 3*d.* per head of the population, or about 1*d.* in the pound on the rateable value of the town.

The capital, 5,500*l.*, will be paid off, and then the annual payment of 330*l.* will cease, and the rates will thus be relieved to the extent of about $2\frac{1}{4}d.$ in the pound on the present rateable value.

The volume of sewage is at a rate of 27 gallons per head of the population, or about eight persons to every ton of sewage.

Bedford.

Population (about) - - - - -	18,000
Rateable value - - - - -	£65,000
Houses - - - - - -	3,500
Waterclosets - - - - - -	3,000

Capital Expended on Works to dispose of the Sewage.

Outlet works, pumping station, and laying out farm - £9,200

The Yearly Cost of disposing of the Sewage.

	£	s.	d.
Capital 9,200*l.* at 6 per cent. to be repaid in yearly instalments - - - - -	552	0	0
Paid for labour, tradesmen bills, coals, &c. in working sewage farm, including amount of rent, rates and taxes, and also cost of seed - - -	3,280	7	8
	3,832	7	8
Less amount received for sale of stock and crops -	3,461	6	0
	£371	1	8

The daily mean flow of sewage is about 700,000 gallons = 3,125 tons, or 1,140,625 tons yearly.

The annual cost to the Corporation in disposing of the sewage is 3,832*l.* 7*s.* 8*d.*, or at a rate of $\frac{51}{64}$ of a penny per ton; they receive for the produce 3,461*l.* 6*s.*, an amount equal to $\frac{46}{64}$ of a penny per ton of sewage, and consequently lose 371*l.* 1*s.* 8*d.*, or about $\frac{5}{64}$ of a penny per ton; or at the rate of $4\frac{3}{4}d.$ per head of the population, or 1*d.* in the pound on the rateable value of the borough.

The volume of sewage is at the rate of 39 gallons per head of the population, or about six persons to every ton of sewage.

The capital 9,200*l.* will be paid off when the rates will be relieved to the extent of about 2*d.* in the pound on the present rateable value.

Blackburn.

Population (about) - - - - -	90,000
Rateable value - - - -	£235,127
Houses - - - - -	16,700
Waterclosets - - - - - -	730
Privies and middens - - - - -	10,574
Privies on "pail" system - - - -	2,690
Ashpits - - - - - -	5,287

The yearly cost of cleansing the privies on both systems is - - - - -	£5,641
Amount received for the refuse - -	1,806
Consequent loss on removal - - -	£3,835

Or at a rate of 10¼*d.* per head of the population, or about 3¾*d.* in the pound on the rateable value of the borough.

CAPITAL EXPENDED in DISPOSING of the SEWAGE.

Damages and cost in Chancery suit, and action at law -	£12,000
Cost of obtaining private Act - - -	6,500
Costs of outfall sewer, and laying out sewage-farm at Pleasington - - - - - -	11,600
Purchase of land at Samlesbury, including expenses of arbitration and easements - - - -	*69,500
Cost of laying out this farm for sewage irrigation -	*7,650
	£107,250

N.B.—* The sums marked thus are for land and works which have not come into profitable use at present.

The YEARLY COST of DISPOSING of the SEWAGE.

Capital 107,250*l.* at 6 per cent., to repay principal and interest. Yearly instalment - - - -	£6,435
Rent of farm at Pleasington - - -	484
Working expenses of farm - - - -	6,523
	13,442
Less sale of produce - - - -	5,781
	£7,661

The mean daily flow of the sewage is 1,500,000 gallons = 6,696 tons, or 2,444,040 tons yearly. The annual cost to the Town Council in disposing of the sewage is 13,442*l.*, or at a rate of $\frac{84}{64}$ths per ton; they receive for it in sale of produce 5,781*l.*, an amount equal to $\frac{36}{64}$ths of a penny per ton of sewage, and consequently lose 7,661*l.*, an amount equal to about $\frac{48}{64}$ths of a penny per ton, or at a rate of 1*s.* 8¼*d.* per head of population.

The yearly loss in cleansing privies - - -	£3,835
,, ,, disposing of the sewage - -	7,661
	£11,496

or at a rate of 2*s.* 6½*d.* per head of population, or 11½*d.* in the pound on the rateable value of the borough.

The borrowed capital amounting to 107,250*l.*, and which involves an annual payment of 6,435*l.*, will cease when the terms have been accomplished, so that the rates will be relieved (at the existing rateable value) to the extent of about 6½*d.* in the pound.

The volume of sewage is at the rate of 17 gallons per head of the population, or 14 persons to every ton of sewage.

CHELTENHAM.

Population (about) - - - - -	45,000
Rateable value - - - - - -	£217,849
Houses - - - - - -	8,725
Waterclosets (about) - - - - -	8,500
Quantity of refuse removed yearly from ashpits (cubic yards) - - - - - - -	3,234
Cost of removing ashes yearly - - -	£324

or at the rate of 2*s.* per cubic yard or about 1¾*d.* per head of population.

CAPITAL EXPENDED for DISPOSING of the SEWAGE.

Purchase of farm and cost of construction of works for sewage utilization - - - - -	£18,000

The Yearly Cost of disposing of the Sewage.

Capital 18,000*l.* at 6 per cent. to repay principal and interest in 30 years - - Yearly instalment		£1,080
Cost of applying sewage to farm - - -		150
Rates and taxes - - - - -		50
Cost of cleaning out sewage tanks - - -		296
		£1,576
Less rent obtained for the farm - -	£800	
Amount for sewage applied to land adjoining the sewage carriers - - - -	156	
Amount received for sludge mixed with house-ash - - - - - -	348	
		£1,304
Consequent loss -		£272

The daily mean flow of the sewage is 1,250,000 = 5,580 tons or 2,036,700 tons yearly. The annual cost to the Improvement Commissioners in disposing of the sewage is 1,576*l.*, or at the rate of $\frac{12}{64}$ths of a penny per ton; they receive for it 1,304*l.*, an amount equal to $\frac{16}{64}$ths of a penny per ton of sewage, and consequently lose 272*l.* or about $\frac{3}{64}$ths of a penny per ton, or at a rate of $1\frac{1}{4}d.$ per head of the population.

The yearly loss in cleansing ashpits - - - -	£324
„ „ in disposing of the sewage - - -	272
	£596

or at a rate of $3\frac{1}{4}$ per head of the population or about three-fourths of a penny in the £ on the rateable value of the district.

The volume of sewage is at the rate of 28 gallons per head of the population, or 8 persons contribute to every ton of sewage.

The capital of 18,000*l.* will be paid off and then the annual payment of 1,080*l.* will cease, and the rates will be relieved to the extent of about $1\frac{1}{4}d.$ in the pound on the present rateable value.

Chorley (Lancashire).

Population (about) - - - - - -	20,000
Rateable value - - - - - -	£54,407
Houses - - - - - - -	4,000
Waterclosets - - - - - - -	200
Privies and middens - - - - -	1,600
Privies "pail" system (about) - - - -	700

The yearly cost of cleansing the privies on both systems is - - - - - - -	£709
Amount received for the refuse - - - -	186
Consequent loss on removal - - - -	£523

or at a rate of $6\frac{1}{4}d.$ per head of the population or about $2\frac{1}{4}d.$ in the pound on the rateable value.

Expenses incurred in disposing of the Sewage.

Purchase of farm at Common Bank - - -	£6,450
Outfall sewer, laying out farm and erecting farm-buildings - - - - - -	4,800
Purchase and laying out of part of Kingsley's farm -	5,300
	£16,550

The Yearly Cost of disposing of the Sewage.

Capital 16,550*l*. at 6 per cent. to repay principal and interest - - - Yearly instalment		£993
The working expenses of the farm - - -		927
		£1,920
Less amount for produce sold - - -	847	
„ rent received for part of Kingsley's farm with sewage - - - -	90	
		£937
		£983

The daily mean flow of the sewage is about 500,000 gallons = 2,232 tons or 814,680 tons yearly. The annual cost to the Improvement Commissioners in disposing of the sewage is 1,920*l*. or at the rate of $\frac{32}{64}$ths per ton; they receive for the produce of the farm, 937*l*., an amount equal to about $\frac{15}{64}$ths per ton of sewage, and consequently lose 983*l*. or about $\frac{17}{64}$ths per ton, or at a rate of 1*s*. per head of the population.

The yearly loss on cleansing privies - - -	£523
„ „ in disposing of the sewage - -	983
	£1,506

or at a rate of about 1*s*. 6*d*. per head of the population, or about 7*d*. in the pound on the rateable value of the district.

The volume of sewage is at a rate of 25 gallons per head of the population, or about nine persons contribute to every ton of sewage.

The capital 16,550*l*. will be paid off and then the annual payment of 993*l*. will cease, when the rates will be relieved to the extent of about 4¼*d*. in the pound on the present rateable value.

Doncaster.

Population (about) - - - - -	20,000
Rateable value - - - - - -	£68,721
Houses - - - - - - -	4,300
Waterclosets - - - - - -	Not known.
Privies - - - - - - -	3,078
Quantity of refuse removed from privies yearly (tons) -	4,400

Cost of cleansing privies yearly, or at the rate of 2*s*. 5¼*d*. per ton - - - -	£539
Amount received for refuse - - -	310
Consequent loss on removal - - -	229

Or at the rate of 1*s*. 0½*d*. per ton, or 2½*d*. per head of the population, or about 1*d*. in the pound on the ratable value of the borough.

Expenses incurred to Dispose of the Sewage.

Outfall works, including pumping-station, engines, pumps, pumping-main, and laying out farm* -	£20,000

The Yearly Cost of disposing of the Sewage.

Capital 20,000*l*., taken at 6 per cent., to repay principal and interest. Yearly instalment - - -	£1,200
Annual cost of pumping sewage to farm - -	300
	1,500
Less improved rent for farm - - - -	470
	1,030

* The land is part of a much larger estate which is the property of the corporation.

The daily mean flow of the sewage is about 600,000 gallons = 2,678 tons, or 977,470 tons yearly. This is pumped to a height of 52 feet. The gross annual cost to the Town Council in disposing of the sewage is 1,500*l.*, or at a rate of about $\frac{23}{64}$ths of a penny per ton; they receive for it (*i.e.*, improved rent of farm) 470*l.*, an amount equal to $\frac{7}{64}$ths of a penny per ton of sewage, and consequently lose 1,030*l.* or $\frac{16}{64}$ths of a penny per ton, or at a rate of 1*s.* 0¼*d.* per head of the population, or 3½*d.* in the pound on the rateable value.

The yearly loss in cleansing privies - - -	£229
" " disposing of the sewage - -	1,030
Total - - - - -	£1,259

Or at the rate of 1*s.* 2¾*d.* per head of the population, or 4½*d.* in the pound on the rateable value of the borough.

The volume of sewage is at a rate of 30 gallons per head of the population, or about eight persons contribute to every ton of sewage.

The capital of 29,000*l.* will be paid off and then the annual payments of 1,740*l.* will cease, and the rates will be relieved to the extent of about 4¼*d.* in the pound on the present rateable value.

Harrogate.

Population (average) - - - - -	12,000
Rateable value - - - - - -	£50,000
Houses - - - - - - -	1,500
Waterclosets - - - - - -	1,620

Expenses incurred to dispose of the Sewage.

Outlet works, and laying out 47 acres of land at Jenny Plain - - - - - -	£1,150
Purchase of Knox Bleachfields - - -	2,200
Purchase of land at Wetherby Lane - - -	1,000
Outlet works, and laying out 13½ acres of land at Wetherby Lane - - - - -	3,484
Estimated cost of laying out farm of 247 acres -	3,216
Damages and costs in Chancery suit (about) - -	9,500
Total - - -	20,550

The Yearly Cost for Disposing of Sewage.

Capital 20,550*l.* at 6 per cent. to be repaid with interest. Yearly instalment - - -				£1,233	0	0
Rent of farm of 247 acres - - -				300	0	0
Rent and expenses of treating the sewage on the 47 acres - - - - -				282	10	5
				£1,815	10	5
Less sale of produce - -	£569	13	1			
Rent of land with sewage at Wetherley Lane - - - -	52	0	0			
				621	13	1
				£1,193	17	4

The daily mean flow of the sewage is about 210,000 gallons, equal to 937½ tons, or about 342,187 tons yearly.

The annnal cost to the Commissioners in disposing of the sewage is 1,815*l.* 10*s.* 5*d.*, or at the rate of $\frac{81}{64}$ths per ton; they receive for the produce 621*l.* 13*s.* 1*d.*, an amount equal to $\frac{28}{64}$ths of a penny per ton of sewage, and consequently lose 1,193*l.* 17*s.* 4*d.*, or about $\frac{53}{64}$ths of a penny per ton, or at the rate of 1*s.* 11¾*d.* per head of the population, or about 5¾*d.* in the pound on the rateable value of the town.

The volume of sewage is at the rate of 18 gallons per head of the population, or about 13 persons contribute to every ton of sewage.

The capital 20,550*l.* will be paid off and then the annual payment of 1,233*l.* will cease, and the rates will thus be relieved to the extent of about 6*d.* in the pound on the present rateable value.

Leamington.

Population (including the districts of Lillington and Milverton) - - - - - -	24,700
Rateable value of the borough of Leamington -	£113,400
Inhabited houses - - - - -	4,500
Waterclosets, average two to a house - - -	8,370
Quantity of refuse from privies removed yearly (cubic yards) - - - - - -	3,000
Cost of cleansing privies yearly, or at the rate of 5*s.* 2¼*d.* per cubic yard, or 7½*d.* per head of the population, or 1½*d.* in the pound in the rateable value -	£780
Amount received for refuse - - - -	Nil.

Capital Expended on Sewage Works.

Outfall works - - - - - -	8,000
Pumping station, including engines and pumps, &c. -	16,239
Cleansing river - - - - - -	1,500
Law costs - - - - - -	5,000
Total - - -	£30,739

The Yearly Cost of disposing of the Sewage.

	£	s.	d.
Capital 30,739*l.*, at 6 per cent., to repay principal and interest. Yearly instalment - -	1,844	6	9½
The annual cost of pumping the sewage -	1,035	0	0
	2,879	6	9½
Less yearly amount received for the sewage -	450	0	0
	£2,429	6	9½

The daily mean flow of the sewage is about 700,000 gallons, equal to 3,125 tons, or about 1,140,625 tons yearly. This sewage is pumped 130 feet high.

The gross annual cost to the Town Council in disposing of the sewage is 2,879*l.* 6*s.* 9½*d.*, or at a rate of $\frac{38}{64}$ths of a penny per ton. They receive for it 450*l.*, an amount equal to $\frac{6}{64}$ths of a penny per ton of sewage, and consequently lose 2,429*l.* 6*s.* 9½*d.* annually, or $\frac{32}{64}$ths per ton, or at a rate of 1*s.* 11½*d.* per head of the population, or 5*d.* in the pound on the rateable value of the borough.

	s.	d.
Yearly loss on cleansing the privies, per head - -	0	7¼
Yearly cost on disposing of the sewage, per head -	1	11½
	2	6¾

The yearly loss by cleansing the privies - - -	£780
" " disposing of the sewage - -	2,430
	£2,210

or about 2*s.* 7*d.* per head of the population, or 6½*d.* in the pound on the rateable value of the borough.

The volume of sewage is at the rate of 28 gallons per head of the population, or about eight persons contribute to every ton of sewage.

The capital, 30,739*l.*, will be paid off and then the annual payment of 1,844*l.* will cease, and the rates will thus be relieved to the extent of about 4*d.* in the pound on the present rateable value.

Merthyr-Tydfil.

Population about - - - - -	55,000
Rateable value - - - -	£135,000
Houses - - - - - -	10,778
Waterclosets - - - - - -	8,000
Privies - - - - - -	2,800

The privies are cleansed at the expense of the occupiers of the houses to which they belong.

Capital Expended on Works to dispose of the Sewage.

Outfall sewer from Troedyrhiew to Ynyscadudug -	£16,003
Building subsidence tanks - - - -	388
Laying out filters and land for irrigation, including drainage and carriers, at Troedyrhiew - -	6,015
Purchase and laying out, draining, and fencing common land at Navigation - - - - -	4,365
Purchase and laying out land at Ynyscadudug -	14,387
Purchase of Tyrybout estate - - - -	3,002
Purchase of Park Newydd estate - - -	9,170
Total - - -	£53,330

The Yearly Cost for disposing of the Sewage.

Capital, 53,330*l.* at 6 per cent., to repay principal and interest. Yearly instalment - - -	£3,200
Cost of distributing the sewage, including working expenses of farm - - - - -	2,392
Rent of land taken on lease - - - -	298
	5,890
Less produce of the farm - - - -	1,623
	£4,267

The mean daily flow of the sewage is 1,200,000 gallons = 5,357 tons or 1,955,305 tons yearly. The annual cost to the Local Board in disposing of the sewage is 5,890*l.*, or at a rate of about $\frac{46}{64}$ths of a penny per ton. They receive for the produce 1,623*l.*, an amount equal to about $\frac{12}{64}$ths of a penny per ton of sewage, and consequently lose 4,267*l.*, or about $\frac{34}{64}$ths of a penny per ton, or at the rate of about 1*s.* 6½*d.* per head of the population, or about 7½*d.* in the pound on the rateable value of the district.

The volume of sewage is at the rate of 22 gallons per head of the population, or about 10 persons contribute to every ton of sewage.

The capital of 53,330*l.* will be paid off and then the annual payment of 3,199*l.* will cease, and the rates will be relieved to the extent of about 5¾*d.* in the pound on the present rateable value.

Rugby.

Population (about) - - - - -	8,400
Rateable value - - - -	£45,000
Houses - - - - - -	1,700
Waterclosets - - - - - -	1,400

Capital Expended on Works for disposing of the Sewage.

Outlet works and tanks and laying out farm - -	£5,800

The Yearly Cost of disposing of the Sewage.

Capital 5,800*l.* at 6 per cent., to be repaid with interest. Yearly instalment		£348	0	0
Rent of 65 acres of land		290	0	0
Rent of 13 acres of land		54	0	0
	£	692	0	0
Less rent of land sublet with the sewage	350 79			
		429	0	0
		£263	0	0

The mean daily flow of the sewage is about 400,000 gallons = 1,785 tons, or 651,525 tons yearly. The annual cost to the Local Board of Health in disposing of the sewage is 692*l.*, or at a rate of $\frac{17}{64}$ths of a penny per ton; they receive an improved rent for the sewage farm, 429*l.*, an amount equal to about $\frac{11}{64}$ths of a penny per ton of sewage per year, and consequently lose 263*l.*, or about $\frac{6}{64}$ths of a penny per ton, or at a rate of $7\frac{1}{2}d.$ per head of the population, or about $1\frac{1}{2}d.$ in the pound on the rateable value of the district.

The volume of sewage is at the rate of 48 gallons per head of population, or about five persons contribute to every ton of sewage.

The capital 5,800*l.* will be paid off, and then the annual payment of 348*l.* will cease, and the rates will thus be relieved to the extent of about 2*d.* in the pound on the present rateable value.

Tunbridge-Wells.

Population (about)	23,000
Rateable value	£142,914
Houses	5,750
Waterclosets	5,635

Capital Expended on Works to dispose of the Sewage.

Purchase of farms, law costs, arbitration expenses, and compensation to tenants and cost of laying out farms to receive the sewage	£87,243	0	0
Cost of cleaning out Summer Hill Lake	744	17	8
Costs of the Chancery suit	3,000	0	0
	£90,987	17	8

The Yearly Cost of disposing of the Sewage.

Capital 90,988*l.* borrowed at 6 per cent., to be repaid with interest. Yearly instalment	£5,459	5	0
Cost of disposing of the sewage, including working expenses of both farms	8,199	0	0
	£13,658	5	0
Less produce of both farms	7,671	0	0
	£5,987	5	0

The mean daily flow of the sewage over both farms is 650,000 gallons=2,902 tons, or 1,059,230 tons yearly. The annual cost to the Local Board in disposing of the sewage is 13,659*l.*, or at the rate of 3*d.* per ton; they receive for the produce 7,671*l.*, an amount equal to $1\frac{3}{4}d.$ per ton of sewage, and consequently lose 5,988*l.*, or about $1\frac{1}{4}d.$ per ton, or at the rate of $5s.\ 2\frac{1}{4}d.$ per head of the population, or about 10*d.* in the pound on the rateable value of the township.

The volume of sewage is at the rate of 28 gallons per head of the population, or eight persons contribute to every ton of sewage.

The capital 90,988*l.* will be paid off, and then the annual payment of 5,459*l.* will cease, and the rates will thus be relieved to the extent of about 8½*d.* in the pound on the present rateable value.

Warwick.

Population (about)	11,000
Rateable value	£43,339
Houses	2,400
Waterclosets	2,000

Capital expended to dispose of the Sewage.

Outlet works, including pumping station, engines, pumping main, and laying out farm	£10,084	18	1

The Yearly Cost of disposing of the Sewage.

Capital 10,084*l.* 18*s.* 1*d.* at 6 per cent., to be repaid with interest. Yearly instalment	£604	18	4½
Cost of pumping sewage	572	11	6
	£1,177	9	10½

The mean daily flow of sewage is about 700,000 gallons = 3,125 tons, or 1,140,625 tons yearly. The annual cost to the Corporation of Warwick in disposing of the sewage has been 1,177*l.* 9*s.* 10½*d.*, or at the rate of three-eighths of a penny per ton, and as they do not receive any profit rent for the farm which they have sublet, they consequently lose the whole of that amount, or about 2*s.* 1½*d.* per head of the population, or 6½*d.* in the pound on the rateable value of the borough.

The volume of sewage is at a rate of 64 gallons per head of the population, or about four persons contribute to every ton of sewage.

The capital 10,085*l.* will be paid off, when the annual payment of 605*l.* will cease, and the rates will thus be relieved to the extent of about 3¼*d.* in the pound on the rateable value.

Wolverhampton.

Population (about)	71,000
Rateable value	£210,000
Houses	14,000
Waterclosets	750
Privies (about)	5,000

Quantity of refuse removed from the privies (yearly) - 36,000 tons.

Cost of cleansing the privies (yearly)	£3,200
Or at a rate of 1*s.* 9¼*d.* per ton.	
Amount received for the refuse	1,600
Consequent loss on removal	£1,600

Or at a rate of 10¾*d.* per ton, or near 6*d.* per head of population.

Capital expended to dispose of the Sewage.

Purchase of farm	£32,000
Cost of reservoirs and other works on farm	6,000
	£38,000

The Yearly Cost for disposing of the Sewage.

Capital 38,000*l.* at 6 per cent. to repay principal and interest.

Yearly instalment - - - - - -	£2,280
Working expenses of sewage farm - - -	4,451
	6,731
Less receipts for sale of produce and valuation of live and dead stock - - - - - -	5,097
Annual loss - - - - - -	£1,634

The mean daily flow of the sewage is 2,500,000 gallons = 11,160 tons, or 4,073,400 tons yearly. The annual cost to the Corporation in disposing of the sewage is 6,731*l.* or at a rate of three-eighths of a penny per ton—they receive for it 5,097*l.*, an amount equal to two-eighths of a penny per ton of sewage, and consequently lose 1,634*l.* or about one-eighth of a penny per ton, or at a rate of 5½*d.* per head of the population, or about 2*d.* in the 1*l.* on the rateable value.

The yearly loss on cleansing privies - - -	£1,600
,, ,, in disposing of the sewage - -	1,634
	£3,234

or at a rate of 10¾*d.* per head of the population, or about 3½*d.* in the 1*l.* on the rateable value of the Borough.

The volume of the sewage is at the rate of 35 gallons per head of the population, or about 6 persons contribute to every ton of sewage.

The capital, 38,000*l.*, will be paid off, and then the annual payment of 2,280*l.* will cease, and the rates will thus be relieved to the extent of about 2¾*d.* in the 1*l.* on the present rateable value.

Report of the Wolverhampton Sewerage Committee on the Result of Farming Operations at Barnhurst.*

1st May, 1876.

Appended is a statement of receipts and expenditure in connexion with the farming operations at Barnhurst, for the year ended Lady-day last.

In reviewing the experience of the past year, it may be remarked that although contagious diseases amongst cattle have been prevalent in the district the corporation stock has been entirely free from this form of disease, and that the losses in live stock comprise only one beast from gripes, one sheep and lamb drowned, and three young pigs which died from inflammation.

The past year generally has been unfavourable to successful sewage farming, owing to the extraordinary and frequent heavy falls of rain. Consequent on this the Barnhurst Estate suffered considerably from floods, causing great damage to the grain crops, decreasing the yield, and injuring the quality; still, with all these drawbacks, your Committee have the satisfaction of presenting a balance sheet showing a profit on the year's working of 1,048*l.* 16*s.* 5*d.* equal to 84*s.* 7*d.* per acre on the 248 acres of land under cultivation, or an increase of 52°/₀ on last year's experience.

In conclusion, your Committee beg to draw the serious attention of the Council and the public to the great damage sustained to crops through acids being allowed to run into the sewers from manufactories in the Borough. This subject was particularly referred to in the Annual Report of your Committee, in November last, and they cannot now too strongly urge upon the manufacturers the importance of neutralizing the acids and other injurious refuse from their works before allowing them to flow or pass into the drains, or of altogether preventing the same from entering the sewers; and unless some such steps are taken your Committee will reluctantly be compelled to ask the Council to instruct the Town Clerk to take proceedings against offending parties, under the 95th section of the Wolverhampton Improvement Act, 1869.

J. Hawksford, *Chairman.*

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* In this report no notice is taken of the interest on the capital expended, 38,000*l.*, amounting to 2,280*l.* per annum, or 2¾*d.* in the pound on the rateable value of the district.

Barnhurst Farm Account, year ended March 25th, 1876.

Receipts.

		£	s.	d.	£	s.	d.
1875. March 25.	To Balance, in bailiffs' and other hands				260	13	6
1876. March 25.	To Wheat sold	176	2	6			
	„ Barley	181	0	0			
	„ Oats	77	2	6			
	„ Rye grass	442	14	10			
	„ Live stock	1,542	7	8			
	„ Hay, straw, &c.	67	15	9			
	„ Mangolds, cabbages, &c.	127	15	4			
	„ Stock taken into Ley	41	4	0			
	„ Miscellaneous receipts, wool, team hire, rents, &c.	186	9	3	2,842	11	10
	„ Balance due to treasurer and others				1,749	15	0
					£4,853	0	4

	£	s.	d.
Valuation on 25th March 1875	2,465	5	6
Expenditure as above for the year ended 25th March 1876	2,128	11	11
	£4,593	17	5

Expenditure.

		£	s.	d.	£	s.	d.
1875. March 25.	By Balance due to treasurer and others				2,533	5	0
1876. March 25.	By Labourers' wages	544	14	11			
	„ Rates, taxes, and bank interest	146	15	6			
	„ Tradesmen's bills	161	3	1			
	„ Corn and seeds	106	11	5			
	„ Hay, straw, &c.	255	19	0			
	„ Manure	50	6	0			
	„ Live stock	854	2	0			
	„ Turnips and cabbages	9	0	0	2,128	11	11
	„ Balances in bailiffs' and other hands				191	3	5
					£4,853	0	4

	£	s.	d.
Receipts year ended 25th March 1876	2,842	11	10
Valuation at Lady Day, 1876, as per Mr. T. J. Barnett's valuation	2,800	2	0
	£5,642	13	10
	4,593	17	5
Profit for the year ending Lady day, 1876	£1,048	16	5

Valuation, 25th March 1874.

	£	s.	d.	£	s.	d.
Live Stock	1,266	5	0			
Hay, straw, corn, and off-going tenants share of labour performed	1,051	5	0			
Implements (at 10 per cent. under actual cost)	482	12	0			
				2,800	2	0

John Bryan,
Accountant Clerk.

West Derby.

Population, about		31,400
Annual rateable value		£163,000
Daily volume of sewage about	gallons	750,000
Number of waterclosets about		3,220
Number of ashpit middens		1,630
About two privies to each midden		3,260
Area of sewage farm	acres	207

Total cost of land and works, 63,350*l.*, or at a rate of about 306*l.* per acre.

Sewage, 750,000 gallons equal to 3,344 tons per day, or about 1,220,560 tons per annum.

63,350*l.* capital at 6 per cent.	per annum	£3,800
Annual working expenses		2,335
Total		£6,135
Less total income		3,350
Total annual cost		£2,785

6,135*l.*, equals a rate of	$1\frac{1}{4}d.$ per ton.
3,350*l.* received, equals	$\frac{3}{4}d.$ „
2,785*l.*, the annual loss	$\frac{1}{2}d.$ „

There are about 24 gallons of sewage per head, or about nine persons to each ton of sewage.

The annual cost is about 1*s*. 9*d*. per head, and 4¼*d*. in the pound.

17,000 tons of privy midden refuse is removed at an annual cost of 700*l*., or at a rate of 9¾*d*. per ton. The refuse is the property of the contractor.

Wrexham.

Population	10,000
Houses	2,000
Waterclosets	1,200
Annual rateable value	£32,000

The sewage flows on to the farm by gravitation, the farmer can take in water from the brook, and does so in dry seasons occasionally.

Area of sewage farm, 84 acres. Leased by corporation at 320*l*. a year. Colonel Jones pays 350*l*., and rents other land, 20 acres, at 40*s*. per acre, or 40*l*. per annum.

104 acres at an annual rental, 390*l*. The tenant only puts sewage on 86 acres.

Dry weather sewage, about 300,000 gallons per day. Wet weather passed to the farm, about 500,000. Flood-waters pass to the river.

Sewage has been applied to the land about six years; Colonel Jones has worked it about four years. Land is open, having a sub-soil of sand and gravel. About five acres are usually under sewage at one time.

Colonel Jones considers that he could with advantage dispose of 500,000 gallons per day all the year round.

Will cultivate about 20 acres of Italian rye-grass. Commenced with three acres, then eight, increased to 17, this next year will be 20. The average cuttings per season have been seven to eight, about 40 tons per season. A single crop has on a portion of the land been 12 tons per acre. The price obtained has been on an average 9*d*. per cwt., or 15*s*. per ton on the ground.

Mangolds, about five acres, 46 tons per acre, sells at 20*s*. per ton. Through the winter the land is dressed with sewage, and some of it warped with the sludge. Ordinarily the sludge is extracted in depositing tanks, four of 180 feet in length, about nine feet wide at top, and three feet deep. Two at a time are in use. The sludge is sold at about 1*s*. 6*d*. per ton.

There is about 1,800 tons of sewage per day, or 657,000 tons per annum.

The corporation main sewerage works cost about 11,080*l*., this expenditure must not however be charged to the sewage-farm, as it is repaid out of the district rate.

The net profit on the sewage-farm to the corporation is 30*l*., or about one-ninetieth of a penny per ton, as the value of the sewage to the ratepayers of Wrexham. Colonel Jones considers that the sewage ought to be given.

Colonel Jones has laid down 1,215 lineal yards of 12-inch pipe carriers, at a cost of about 2*s*. 6*d*. per yard, or about 152*l*.

The capital laid out by Colonel Jones is 700*l*.

About 40 head of stock are kept on the farm, milch cows.

Colonel Jones considers that there is more certainty in sewage farming than in ordinary farming, as there is the moisture available at all times. The trouble in wet seasons is in selling and in removing the crop from the land.

There is more produce on sewaged land in wet seasons than in dry seasons; but there is not so good a demand because there is also more grass on unsewaged land, which, in a dry season, is burnt up and consequently is for the time unproductive.

Hafod-y-Wern Farm.

1874–5.—84 acres gross measurement: Rent and taxes, &c. at 5*l.* per acre.

Profit and Loss Account.

1875. Dr.	£	s.	d.
Feb. 1.			
To Balance of sundries and implement account	32	4	0
" Rent and taxes account	0	9	8
Barley crop, couch field* account	15	18	6
" 1873 crops account	3	17	3½
Interest.			
" One year on floating capital, 5 per cent on 1,830*l.*	91	10	0
Payment into Sinking Fund.			
" 5 per cent. on 479*l.*	23	19	0
Balance profit	276	4	6½
	£444	3	0

1875. Cr.	Acres.	£	s.	d.
Feb. 1.				
By Balance Italian rye-grass account	13	184	16	10½
" Mangolds "	5	46	8	10
" Filter beds (market garden) account	4	20	15	10½
" Permanent pasture acct.	41	58	8	4
" Oat crop "	2½	11	5	6
" Wheat crop "	6	56	10	11
" Potato "	2	2	6	4
" Carrots "	1½	0	17	9
" Dairy "	—	44	15	7
" Tank sludge "	1	17	17	0
Couch field farm, Dr. Side	6	—		
Total acres in crop	82			
		£444	3	0

1875–6.—104 acres gross measurement.

1876. Dr.	£	s.	d.	£	s.	d.
Feb. 1.						
To Balance of sundries and implement account				37	4	0
" Couch field (oats) account*				48	6	1
" 1874 crops' account				19	9	4
Interest.†						
3 months on 1900*l.* at 5 per cent.	23	15	0			
9 months on 1,300*l.*	48	15	0	72	10	0
Payment to Sinking Fund.						
" 5 per cent. on 550*l.* for permanent improvements				27	10	0
† Balance profit				271	18	6½
				£476	17	11½

1875. Cr.	Acres.	£	s.	d.
Feb. 1.				
By Balance Italian rye-grass account	17	275	1	1
" Mangolds "	5	28	0	3
" Filter beds (market garden) account	4	17	19	3½
" Permanent pasture	56	30	14	4
" Oat crop acct.	4	6	12	6
" Barley crop "	4½	23	15	9
" "Odd crops" (potatoes, turnips, and carrots)	5	9	2	10½
" Dairy account	—	67	13	6½
" Tank sludge account	—	13	3	4
" Rent "	—	4	15	0
Couch field farm "	6	—		
Total acres in crop	100½			
		£476	17	11½

* This field lies above sewage tanks level, so can get no liquid.

† The main part of dairy stock was handed over to Mr. George Jackson on 15th May 1875 by valuation, and hence the dairyman's profit for nine months, being an unknown quantity, is in addition to this balance. He seems content.

(Signed) Alfred S. Jones, Lieut.-Colonel.

TREATMENT OF SEWAGE BY LAND FILTRATION.

Kendal.

Population, about	13,700
Annual rateable value	£44,600
Houses	2,727
Waterclosets	450
Privies cleansed at the expense of the owners of the houses to which they belong	

Expenses incurred to dispose of the Sewage.

Purchase of sewage farm, repairs, cost of outlet works tanks, preparing filter beds, and levelling land	£18,871

The Yearly Cost of disposing of the Sewage.

Capital, 18,871*l.*, borrowed at 6 per cent., to be repaid with interest in 30 years. Yearly instalment	£1,132
Paid for labour and materials in working sewage farm	110
	£1,242
Less receipts from sale of produce	495
	£747

The mean daily flow of the sewage is about 750,000 gallons, equal to 3,348 tons, or 1,222,098 tons yearly. The annual cost to the Town Council in disposing of the sewage is 1,242*l.* 5*s.* 2½*d.*, or at a rate of three-eighths of a penny per ton. They receive for the produce 495*l.*, an amount equal to one-eighth of a penny per ton of sewage, and consequently lose 747*l.* 5*s.* 2½*d.* or about one-fourth of a penny per ton, or at a rate of 1*s.* 1*d.* per head of the population, or 4*d.* in the pound on the rateable value of the borough.

The volume of sewage is at the rate of 55 gallons per head of the population, or about four persons contribute to every ton of sewage.

The capital, 18,871*l.*, will be paid off, and then the annual payment of 1,132*l.* will cease, and the rates will thus be relieved to the extent of about 6*d.* in the pound on the present rateable value.

PRECIPITATION OF SEWAGE-SLUDGE IN TANKS.

Birmingham.

Population (about)	350,000
Rateable value	£1,229,844
Houses	83,420
Waterclosets (about)	8,000
Privies, old system	35,000
„ pail system	7,000
Ashpits	25,000
Quantity of refuse removed in 1875 from the privies and ashpits (tons)	128,512
Removing contents	£35,180
Cost of cleansing privies and ashpits yearly, and Amount received for refuse	5,885
Consequent loss on removal, or at the rate of 4*s.* 6¾*d.* per ton, or 1*s.* 8*d.* per head of the population, or 5½*d.* in the pound on the rateable value of the borough	£29,295

Expenses incurred to dispose of the Sewage.

Purchase of land (farm)	£45,400
Levelling, draining, and laying out	11,250
Outlet works and tanks	58,880
Cost of promoting bill in Parliament	10,644
Compensation to Right Hon. Sir C. B. Adderley, M.P.	6,000
	£132,174

The Yearly Cost of disposing of the Sewage.

Capital, 132,174*l.*, at 6 per cent., to repay principal and interest. Yearly instalment				£7,930	8	9½
Part of farm held on lease, yearly rent				855	0	0
Yearly expense of cleansing tanks, removing and digging in 109,500 tons of sludge				12,778	0	0
Yearly cost of General Scott's process				332	0	0
Yearly working expense of farm				2,547	0	0
				£24,442	8	9½
Less amount received for portion of sludge sold	£202	10	0			
Amount received for cement sold (General Scott's process)	179	0	0			
Amount received for sale of farm produce	2,130	0	0	2,511	10	0
				£21,930	18	9½

The daily mean flow of the sewage is about 12,000,000 gallons, = 53,571 tons, or 19,553,415 tons yearly. The annual cost to the Town Council in disposing of the sewage is 24,442*l.* 8*s.* 9½*d.*, or at the rate of about nine

thirty-seconds of a penny per ton. They receive for it 2,511*l.* 10*s.* 0*d.*, an amount equal to about one thirty-seconds of a penny per ton of sewage, and consequently lose 21,930*l.* 18*s.* 9½*d.*, or about one-fourth of a penny per ton, or at the rate of 1*s.* 3*d.* per head of the population.

		s.	*d.*
Loss per head of the population in cleansing privies	-	1	8
" " disposing of sewage	-	1	3
Total loss	-	2	11

or 4½*d.* in the pound on the rateable value of the borough.

The yearly loss by cleansing the privies	-	£29,295
" " disposing of the sewage	-	21,931
Total	-	£51,226

or about 2*s.* 11*d.* per head of the population, or about 10*d.* in the pound on the rateable value of the borough.

The volume of sewage is at a rate of 34 gallons per head of the population, or about 6 persons contribute to every ton of sewage.

The capital, 132,174*l.*, will be paid off, when the rates will be relieved to the extent of about 1½*d.* in the pound on the present rateable value.

TREATMENT OF SEWAGE BY CHEMICALS.

Coventry.

Population (about)	-	40,000
Rateable value	-	£101,438
Houses	-	10,400
Waterclosets (about)	-	5,000
Privies	-	800
Quantity of refuse removed yearly (loads)	-	6,600
Cost of cleansing privies yearly and removing contents		£1,050
Amount received for refuse	-	110
Consequent loss on removal	-	£940

or at the rate of 2*s.* 10*d.* per load, or 5¾*d.* per head of population.

Expenses incurred to dispose of the Sewage.

Purchase of farm for irrigation at Whitley, not used for that purpose, but let at an annual rent of 718*l.*	-	£27,000
The yearly cost to the corporation of disposing of the sewage is	-	*Nil.*

The Yearly Cost to the General Sewage and Manure Company is as under:

Cost of works and plant	-	£12,000
Capital 12,000*l.* at 6 per cent. to repay principal and interest. Annual instalment	-	720
Working expenses of the process for treating the sewage 122½ hours weekly instead of 168 hours	-	2,850
		£3,570

The daily mean flow of the sewage is 2,000,000 gallons = 8,938 tons or 3,258,370 tons yearly. The annual cost to the General Sewage and Manure Company in disposing of the sewage is 3,570*l.*, and as there is not a sale for the manure produced from the process carried out by the company, the consequent loss is the above named amount equal to about one-fourth of a penny per ton of sewage, or at the rate of 1*s.* 9¼*d.* per head of the population.

The yearly loss on the cleansing of the privies - -	£940
The yearly loss in disposing of the sewage - -	3,570
	£4,510

or at a rate of about 2*s.* 3*d.* per head of the population or about 9½*d.* in the pound on the rateable value of the city.

The volume of sewage is at a rate of 50 gallons per head of the population, or about 5 persons contribute to every ton of sewage.

BOLTON-LE-MOORS.

Population (about) - - - - - -	93,100
Rateable value - - - - - -	£311,563
Houses - - - - - -	18,249
Waterclosets - - - - - -	758
Privies and middens - - - - -	10,380
Privies, "pail system" - - - -	700
Weight of refuse removed yearly from privies on both systems (tons) - - - - -	51,290
Yearly cost of cleansing privies on both systems and removing contents - - - - -	£6,645
Amount received for refuse - - - -	4,494
Consequent loss on removal or at the rate of 10*d.* per ton, or 5½*d.* per head of population - - -	£2,151

CAPITAL EXPENSES incurred to DISPOSE of the SEWAGE.

Intercepting sewers - - - - -	10,286
Sewage defæcating works - - - -	16,578
	£26,864

The YEARLY COST of DISPOSING of the SEWAGE.

	£	*s.*	*d.*
Capital 26,864*l.* at 6 per cent. to repay principal and interest. Yearly instalment - -	1,609	18	4¾
Cost of treating the sewage by the M. C. process for only 57½ hours a week, instead of continuously for 168 hours in every week of seven days - - - - - -	1,006	17	0
	£2,616	15	4¾

The daily mean flow of the sewage is about 2,500,000 gallons = 11,161 tons or 4,073,765 tons yearly. The annual cost to the Town Council in disposing of the sewage is 2,616*l.* 15*s.* 4¾*d.* or at the rate of about one-eighth of a penny per ton, or 6¾*d.* per head of population, and this is the consequent loss as there is no sale for the "sludge," the residuum of the process. If the sewage was treated for the whole of the 24 hours, and for every day in the week by this process, the loss would be at the rate of about three-eighths of a penny per ton, or 1*s.* 8¼*d.* per head of the population, and this, too, for only about one-half of the sewage of the borough, for the other half flows direct into the river.

The yearly loss in cleansing the privies - -	£2,151
„ „ in disposing of the sewage - -	2,617
	£4,768

or at a rate of 1*s.* 0¼*d.* per head of the population or 3½*d.* in the pound on the rateable value of the borough.

The volume of sewage is at a rate of 27 gallons per head of the population, or eight persons contribute to every ton of sewage.

The capital, 26,864*l.* will be paid off in 30 years, and then the rates will be relieved to the extent of about 1¼*d.* in the pound on the present rateable value.

Leeds.

Population (about) - - - - -	285,000
Rateable value - - - - -	£945,141
Houses (about) - - - - -	57,000
Waterclosets (about) - - - - -	8,000
Privies and middens - - - - -	15,598
Quantity of refuse removed yearly from privies and middens - - - - - loads	80,000
Cost of cleansing privies and middens yearly, and removing contents - - - - -	£27,000
Less amount received for the refuse - - -	9,000
Consequent loss on removal - - - -	£18,000

or at the rate of 4*s.* 6*d.* per load; or about 1*s.* 2¾*d.* per head of the population; or 4½*d.* in the pound on the rateable value of the borough.

Expenses incurred to dispose of the Sewage.

Experimental and permanent works for A. B. C. process - - - - - -	£57,000
Borwick's machines for drying sludge - - -	4,000
	£61,000

The Yearly Cost of disposing of the Sewage.

Capital, 61,000*l.* at 6 per cent. to repay principal and interest. Yearly instalment - - -	£3,660
Yearly cost of treating the sewage by A. B. C. process	15,000
	£18,660

The daily mean flow of the sewage is about 12,000,000 gallons, = 53,571 tons, or 19,553,415 tons yearly. The annual cost to the town council in disposing of the sewage is 18,660*l.*, or at the rate of about one-fourth of a penny per ton, or 1*s.* 3½*d.* per head of the population, or about 4¾*d.* in the pound on the rateable value of the borough, and this is the consequent loss, there being no sale for the "sludge," the residuum of the process.

	s.	d.
Loss per head in cleansing privies - - -	1	2¾
Loss per head in disposing of the sewage - -	1	3½
	2	6¼

The yearly loss on cleansing the privies - -	£18,000
The yearly loss in disposing of the sewage - -	18,660
	£36,660

or at the rate of 2*s.* 6¼*d.* per head of the population, or 9¼*d.* in the pound on the rateable value of the borough.

The volume of sewage is at a rate of 42 gallons per head of population, or about six persons contribute to every ton of sewage.

The capital, 61,000*l.*, will be paid off, and then the rates will be relieved to the extent of about 1*d.* in the pound on the present rateable value.

Bradford.

Population (about) - - - - -	173,723
Rateable value - - - - -	£745,671
Houses - - - - - -	34,000
Waterclosets - - - - - -	4,050
Privies - - - - - - -	11,500
Ashpits - - - - - -	16,500
Weight of refuse removed yearly from privies on both systems - - - - - tons	56,200

The yearly cost of cleansing the privies and ashpits, and removing refuse which is the property of the contractor - - - - - - -	£8,000
Railway waggons for carrying refuse, cost 4,800*l.* at 6 per cent., to repay principal and interest in 30 years -	288
Consequent loss on removal - - - -	£8,288

or at the rate of $11\frac{1}{2}d.$ per head of the population, or about $2\frac{3}{4}d.$ in the pound on the rateable value of the borough.

Expenses incurred to dispose of the Sewage.

Outfall works, tanks, and so-called filters - -	£60,000

The Yearly Cost of disposing of this Sewage.

Capital 60,000*l.* at 6 per cent. to repay principal and interest. Yearly instalment - - -	£3,600
Yearly cost of defæcating the sewage - - -	6,276
Total - - -	£9,876

The mean daily flow of sewage is about 8,000,000 gallons, = 35,714 tons, or 13,035,610 tons yearly. The annual cost to the corporation in disposing of the sewage is 9,876*l.*, or at a rate of about one-sixth of a penny per ton, or $1s.\ 1\frac{5}{8}d.$ per head of the population, or about $3\frac{1}{4}d.$ in the pound on the rateable value of the borough, and as there is no sale for about 7,000 tons of sludge yearly produced, the consequent loss to the borough is the above stated sum.

Yearly loss in cleansing privies - - -	£8,288
Yearly loss in disposing of sewage - - -	9,786
Total - - -	£18,074

or at a rate of $2s.\ 1d.$ per head of the population, and about $6d.$ in the pound on the rateable value.

The volume of sewage is at a rate of 46 gallons per head of the population, or about five persons contribute to every ton of sewage.

The capital, 60,000*l.*, when paid off, will relieve the rates to the extent of about $3\frac{1}{4}d.$ in the pound on the present rateable value.

Halifax.

Population (about) - - - - -	68,000
Rateable value - - - - -	£262,581
Houses - - - - - - -	11,218
Waterclosets - - - - - -	2,600
Privies on old system - - - - -	1,500
Privies on the "Goux" system - - -	3,159
Yearly cost to the corporation of cleansing "Goux" privies - - - - - - -	£1,896
Yearly cost to the corporation of cleansing common privies - - - - - -	1,100
	£2,996

The content is the property of the company and the contractor, and the consequent loss to the corporation is 2,996*l.*, or at the rate of about 10¾*d.* per head of the population.

Expenses incurred to dispose of the Sewage.

Outfall works and tanks - - - - -	£15,954
Cost of chancery suit - - - - - -	4,100
	£20,054

The Yearly Cost of disposing of the Sewage by subsidence only.

Capital 20,054*l.* at 6 per cent., to repay principal and interest.—Yearly instalment - - -	£1,202
Cost of cleaning out tanks - - - -	213
	£1,415

The mean daily flow of the sewage is 2,500,000 gallons, = 11,160 tons, or 4,073,400 yearly. The annual cost to the town council in disposing of the sewage is 1,415*l.*; the sewage is not utilized, and they consequently lose the above amount.

Yearly loss of cleansing privies on both systems -	£2,996
Yearly loss in disposing of the sewage by subsidence only - - - - - - -	1,415
	£4,411

or at a rate of 1*s.* 3½*d.* per head of the population, or 4*d.* in the pound on the present rateable value of the borough.

The volume of sewage is at a rate of 37 gallons per head of the population, or about six persons contribute to every ton of sewage.

The capital, 20,054*l.*, will be paid off, and then the annual payment of 1,202*l.* will cease, when the rates will be relieved to the extent of about 1*d.* in the pound on the present rateable value.

TREATMENT OF EXCRETA BY THE PAIL SYSTEM.

Rochdale.

Population (about) - - - - -	67,000
Rateable value - - - - - -	£222,000
Houses - - - - - -	14,388
Waterclosets - - - - - -	350
Privies on old system - - - - -	2,844
Privies on the "pail" system - - - -	5,462

Expenses incurred to cleanse Privies constructed on "pail" system.

Cost of works and plant (about) - - -	£10,000
Weight of excreta removed in 1875, from privies on "pail" system (tons) - - - -	4,224
Weight of house ash removed to be mixed with excreta (tons) - - - - - -	7,650
	11,874

The Yearly Cost of cleansing the Pail Privies.

Capital 10,000*l.* at 6 per cent. to repay principal and interest in 30 years. Yearly instalment - - -	£600
Or at the rate of 1*s.* per ton of excreta and ash.	
Cost of collection—11,874 tons of excreta and ash -	3,405
Or at a rate of 5*s.* 8¾*d.* per ton.	
Cost of manufacturing manure - - -	3,651
Or at a rate of 5*s.* 4½*d.* per ton.	
	7,656
Or together 12*s.* 1¼*d.* per ton.	
Less 2,002 tons manure sold at the estimated value of 1*l.* per ton - - - - - -	2,002
	£5,654

There is not a ready sale for the manure; consequently there is in stock at the works about 7,000 tons, and none of the excreta have since April 1875 been manufactured into manure.

The Yearly Cost of cleansing the Privies and Middens.

Weight of refuse removed (tons) - - -	13,736
Cost of cleansing - - - - -	£1,919
Or at a rate of 2*s.* 9½*d.* per ton.	
Amount received for 5,736 tons sold, the remainder 8,000 tons are thrown away on "tips" - -	549
Consequent loss - - - - -	£1,370

Or at a rate of about 2*s.* per ton, or about 4¾*d.* per head of the population.

Expenses incurred to only intercept the sewage, and not defæcate it, and to discharge it into the river below the town mill-weir—

Cost of sewer - - - - - -	20,000*l.*
Capital 20,000*l.* at 6 per cent. to repay principal and interest. Yearly instalment - - - - -	1,200*l.*

The daily mean flow of the sewage is 1,250,000 gallons = 5,580 tons or 2,036,700 tons yearly. The annual loss to the Corporation in constructing the intercepting sewer is 1,200*l.* or at a rate of one-fourth of a penny per ton of sewage, or 4¼*d.* per head of the population.

The yearly loss on cleansing the privies "pail" system is	£5,654
The yearly loss on cleansing the privies and middens -	1,370
The yearly loss in constructing the intercepting sewer -	1,200
	£8,220

Or at a rate of 2*s.* 5½*d.* per head of the population, or 8¾*d.* in the 1*l.* on the rateable value of the Borough.

The borrowed capital 10,000*l.* for the pail system, which involves an annual payment of 600*l.*, will cease at the end of the term for which this sum has been borrowed.

The volume of sewage is at a rate of 19 gallons per head of the population, or about 12 persons contribute to every ton of sewage.

Comparison of the Loss of disposing of Town Sewage in proportion to the Annual Rateable Value of the Town.

By Irrigation plus Scavenging.

Name of Town.	Annual Rateable Value.	Annual Cost in the Pound.
1. Banbury - - - -	£34,104	1*d.* in the pound.
2. Bedford - - - -	65,000	1*d.* „ „
3. Blackburn - - - -	235,127	11½*d.* „ „
4. Cheltenham - - -	217,849	¾*d.* „ „
5. Chorley, Lancashire - -	54,407	7*d.* „ „
6. Doncaster - - - -	68,721	3½*d.* „ „
7. Harrogate - - -	50,000	5¾*d.* „ „
8. Leamington - - -	113,400	6½*d.* „ „
9. Merthyr Tydfil - - -	135,000	7½*d.* „ „
10. Rugby - - - -	45,000	1½*d.* „ „
11. Tunbridge Wells - - -	142,914	10*d.* „ „
12. Warwick - - - -	43,339	6½*d.* „ „
13. Wolverhampton - - -	210,000	3½*d.* „ „
14. West Derby - - -	163,000	5¼*d.* „ „
15. Wrexham - - - -	32,000	Nil.

By Chemicals plus Scavenging.

16. Birmingham - - -	£1,229,844	10*d.* in the pound.
17. Coventry, by a company - -	101,438	To the corporation, Nil for disposing of sewage; but at 5¼*d.* in the pound for scavenging.
18. Bolton-le-Moors - - -	311,563	3½*d.* in the pound.
19. Leeds - - - -	945,141	9¼*d.* „ „
20. Bradford - - - -	745,671	6*d.* „ „

By the Pail System at Rochdale. The Crude Sewage flows into the River.

21. Halifax - - - -	262,581	4*d.* in the pound. The crude sewage flows into the river.
22. Rochdale - - - -	£222,000	8¾*d.* in the pound.

By Land Filtration at Kendal.

23. Kendal - - - -	£44,600	4*d.* in the pound.

This abstract is not in all respects a fair comparison of the relative costs the local rates will have to bear in some of the towns named, as in the case of Bolton, where not half of the sewage is dealt with, and even this is done in a manner which will not be sanctioned under a Rivers Pollution Prevention Act. At Rochdale the crude sewage of the town flows direct into the river, a state of things which certainly cannot be continued, and only a portion of the town is at present supplied with pails; and, as we have shown by working out the figures furnished in the local return, not quite one fourth of the excreta of the population said to be supplied with pails is accounted for.

Those towns which have purchased, or leased, land for sewage-farms, as Banbury, Bedford, Wrexham, Wolverhampton, Cheltenham, and Doncaster, show the best results, and levy the lowest rates, and we consider that longer experience will produce even much better results, and in time will show an available income. At Chorley, West-Derby, and Tunbridge-Wells there are good estates to set off against the money expended, the value of which estates will not diminish. At Leeds, Bradford, and Halifax there are only sewage-mud-tanks and so-called filters, with some unprofitable machinery which will not improve in value, and much larger costs must be incurred in these towns before all the sewage can be clarified in the best practicable manner. At Birmingham a large additional purchase of land upon which to purify the sewage is contemplated, and such expenditure will be the best yet made by the local authority. Birmingham is an instance of a town which would not move voluntarily; and then, being driven to extremities by legal restraints, worked unwillingly, bit-by-bit, and in sewering arrangements throwing the town back in its health returns, by compelling a retention of excreta upon the premises in the vain hope by such means to so lessen the polluting property of the sewage at the outlet as to avoid further litigation. Experience has, however, shown that stopping house drainage and discountenancing waterclosets has only slightly diminished the polluting property of the sewage, but not to any appreciable degree which can be accepted as a purification of the river water.

We have explained in this report that sewage, with or without the excreta from waterclosets is sewage, and that the entire excreta of a town population added to the waste-water is, by volume, only about as 1 to 100, consequently the capacity of sewers need not be enlarged; steam pumping power (if required) need not be increased, nor need the area of the land upon which to treat the sewage be added to; neither need there be one shilling more expended per annum on any process connected with the disposal of the sewage; but, on the contrary, the land irrigated will be made more profitable.

At Doncaster, Leamington, and Warwick the rates levied are for the purpose of paying the interest and instalments to redeem the large sums which have been expended upon steam-pumping establishments and cast-iron sewage-mains. At Tunbridge-Wells, West-Derby, and Merthyr-Tydfil, local conditions have necessitated large outlays of capital on the estates and the works for conducting the sewage to the sites, preparing the grounds, and constructing permanent sewage-carriers. These works have been very costly. Longer experience in working the farms will, we anticipate, by improving the income from the produce to be grown, very much lessen the present rates in aid.

It may be noted in the details of the several towns described, as at Blackburn, Harrogate, and at Tunbridge Wells, that very large sums have been paid in parliamentary and legal costs, and we have charged these items to the capital accounts in each case as against sewage irrigation, which of course increases the local rate, but it may fairly be said that such items are not necessarily parts of the expenses to be incurred in providing sewage-farms. Some towns suffer much more than others by reason of local opposition, and litigation before parliamentary committees, or, under the powers of the Lands Clauses Act, by arbitration. Land rented at 20*s*. or 30*s*. per acre, when required for a sewage-farm, is sometimes valued at several hundreds of pounds per acre, and in the case of Blackburn, portions of the land obtained for sewage irrigation purposes has cost about *one hundred and fifty years' purchase.* These difficulties and excessive charges very much retard local improvements and tend to throw the question of sewage irrigation back; it is, however, only a

repetition of opposition which every improvement in civilization has had to fight through.

The list of patents taken out to deal with town sewage (Appendix No. 6) shows how much interest the question has excited, and now excites, but large as this list is it furnishes only indirect evidence as to the vast sums of money expended and lost in working some of these patents. It would appear that to learn the lesson that money cannot be made out of sewage-sludge is very difficult, as over and over again it has been proven that there is no commercial value in it. The Leicester works proved this many years since, and every independent chemist of known repute has stated the fact when called upon to analyse sewage-mud. Neither is this mud capable of being fortified by an admixture of chemicals which shall give it a paying commercial value. The sludge is coarse, crude, sloppy, heavy, and very retentive of the water with which it is combined. In 100 tons of sewage-sludge, as it is removed from the tanks, there is not less than 90 tons of water, which in this form is worthless, and by itself the mud will not readily dry, but mixed with ashes, and other forms of towns refuse, it can be made portable and may then, in some cases, be sold to farmers at a low rate, say from 1*s.* to 2*s.* per ton. When the cost of carting is taken into account this will be its full agricultural value.

At Banbury the mixed sewage sludge, ashes, and street sweepings are given away, although the town is situate in an agricultural district.

At Leamington about 3,000 cube yards of solid refuse, costing 780*l.* to collect per annum, is also given away.

At Doncaster, Bedford, and Leamington, where the lands irrigated are light and free, the crude sewage is pumped direct to the land as it comes from the sewers, and being distributed from temporarily formed carriers, which at intervals are ploughed up. There is no nuisance, but the lands are benefited by the amount of warping they get. At Chorley the crude sewage is also placed on heavy land, which has however been drained.

At Cheltenham the sewage-farm is clay, and the area is small in proportion to the population, but dressings of sewage are sold to the adjoining farmers at a price per acre of 7*s.*, or as may be agreed upon; and in this direction we anticipate that many towns when they have established sewage-farms will find relief. In a dry season the contrast of the green fields of a sewage-farm with the parched, bare, and brown meadows adjoining is very striking. In the early spring the sewage farmer may have grass many weeks before there is any to cut upon ordinary meadows, and the weight of grass obtained is far in excess of any unirrigated crops.

We furnish plans of the sewage farms at Bedford, Doncaster, Tunbridge Wells, Wolverhampton, and West Derby. The details of sewage carriers, and modes of distribution can, however, only be learned to advantage by personal inspection.

Kendal is peculiarly situated, as the land upon which the sewage is clarified is light, open, and washed on its margins by the river, which conditions permit of land filtration over a small area, in comparatively large volumes, at a reasonable cost.

Analyses of Sewage-Sludge as treated and fortified with Chemicals.*

In order to ascertain the value of the fertilizing properties of sewage and excreta, and also of the manures manufactured therefrom, and of their commercial value to the farmer, we collected samples at Bolton, Bradford, Leeds, Coventry, Rochdale, and Halifax, and caused them to be analyzed by Dr. A. Voelcker, F.R.S., and the following is his report thereon :—

Report by Dr. Voelcker, F.R.S.—On the Fertilizing and Commercial Value of Sewage and Night-soil Manures.

The fertilizing and commercial value of sewage-sludge and of portable manures prepared from sewage, night-soil manures, and of common farmyard manure, chiefly depends upon the proportions of phosphate of lime, potash, and nitrogen which these fertilizers contain.

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* See also Appendices Nos. 1, 2, 3, 4.

These fertilizing constituents of manures can be bought at the present time in the form of concentrated artificial manures, such as guano, bone-dust, sulphate of ammonia, &c. at the following rates:

Phosphate of lime at - - -	1*d.* per lb.
Potash - - - - -	2*d.* ,,
Nitrogen calculated as ammonia at -	8*d.* ,,

I need hardly say that in such concentrated forms phosphate of lime, potash, and ammonia have a much greater value than they possess in the shape of manures, the bulk of which mainly consists of materials without value and occurring in abundance in almost every kind of soil.

I would, however, direct attention to the fact that according to my own experience, and that of others, sewage manures, night-soil manures, and ordinary farmyard manure contain but little ready formed ammonia, and that by far the largest proportion of the nitrogen in these manures occurs in them in the shape of nitrogenous organic matters, in which form nitrogen is less efficaceous; and, in consequence less valuable than in the form of ready formed ammonia; or, salts of ammonia.

In estimating the theoretical value of manures, the nitrogen is generally assumed to be present in sewage and similar bulky manures in the form of ammonia; or, at all events, to have the same value as the nitrogen in the salts of ammonia. This, in my opinion, is a mistake, and the nitrogenous constituents of sewage manures are valued at too high a rate, if their nitrogen is calculated into ammonia, and 8*d.* allowed for each lb. of the calculated amount of ammonia. In order to avoid the charge of having put too low an estimate upon the fertilizing constituents of sewage-manures, I have allowed in the estimate 8*d.* per lb. for the calculated amount of ammonia, which the nitrogenous matters, in a ton of manure, are capable of gradually producing under the most favourable circumstances on their final decomposition.

The following tabular statement shows at a glance the theoretical or calculated money value of the different sewage manures which were submitted to me for analysis:—

THEORETICAL OR ESTIMATED MONEY VALUE OF ONE TON OF THE TREATED SEWAGE-SLUDGE.

	£	*s.*	*d.*
(1.) Bolton sludge, from the M. and C. sewage process* -	0	9	8½
(2.) The same dried, leaving 15 per cent. of moisture in the sludge - - - - - - -	1	1	1
(3.) Solids drained from sewage before the liming process at Bradford - - - - - -	0	11	0½
(4.) The same with 15 per cent. of moisture - -	0	19	3
(5.) Bradford Corporation Sewage Outfall Works sludge from drying pits, no artificial heat being used -	0	4	8
(6.) The same, with 15 per cent. of moisture - -	1	0	0½
(7.) Deposit from the sewage of Leeds treated by the A. B. C. process† - - - - - -	0	8	4½
(8.) The same with 15 per cent. of moisture - -	0	16	8½
(9.) Manure produced by the General Sewage Manure Company at Coventry - - - - -	0	16	9½
(10.) Rochdale manure - - - - - -	0	15	11½
(11.) Manure manufactured by the Goux Company at Halifax - - - - - - -	0	17	7

According to the most reliable statements the separation of the suspended matters of sewage by precipitation and filtration, and the production of one ton of dried sewage deposits, apart from the costs of the precipitation agents which are used, entails an expense of about 30*s.* for each ton of portable dried sewage

* M. and C. are the initials of the patentees. The ingredients used are lime, carbon, house-ashes, soda, and per-chloride of iron.

† A. B. C. are the initials of the chief ingredients used in this process, as Alum, Blood, and Clay.

manure. It is evident, therefore, that the cost of manufacture considerably exceeds the theoretical or calculated money value of every one of the sewage deposit manures, the composition of which is given in the results of analysis in Appendices Nos. 1, 2, 3, pages 39, 43, 44, 48, 51, 54, and 59. The estimated money value of sewage and night-soil manures, as has been stated already, does not fairly represent their real commercial value. The bulk of all the samples submitted to me for analysis consists of matters which occur in abundance in almost all soils, and which at any rate have no commercial value, or rather, have a negative value, inasmuch as carriage has to be paid for them, and the application of bulky manures necessarily is more expensive than that of concentrated manures, such as guano or bone-dust. It is, therefore, manifestly practically wrong to estimate the money value of such bulky and poor manures by the same standard of prices at which the commercial value of guano, bone-dust, sulphate of ammonia, and similar concentrated artificial manures are estimated. A more rational and correct estimate of the true value of sewage and night-soil manures is obtained by comparing them with ordinary farmyard manure, and the price which is paid for the latter.

Good farmyard manure, I find, contains on an average in the ton 6½ lbs. of soluble phosphate of lime, 8½ lbs. of insoluble phosphate of lime, 13 lbs. of potash, and nitrogen equal to 17½ lbs. of ammonia.

By allowing for soluble phosphate of lime 2*d.* per lb., the same price for potash, 1*d.* per lb. for insoluble phosphate of lime, and 8*d.* per lb. for ammonia, the calculated money value of a ton of farmyard manure amounts to 15*s.* 7½*d.*, as will be seen from the following figures :—

	s.	*d.*
6½ lbs. of soluble phosphate of lime, worth, at 2*d.* per lb.	1	1
8½ lbs. insoluble ,, ,, 1*d.* ,,	0	8½
13 lbs. potash ,, ,, 2*d.* ,,	2	2
Nitrogen equal to 17½ lbs. of ammonia, calculating ammonia at 8*d.* per lb. - - - - -	11	8
Total calculated money value of a ton of farmyard manure - - - - - -	15	7½

It thus appears that if we estimate the money value of good farmyard manure, according to the same rules at which the principal fertilizing constituents in the dung can be bought in concentrated manures, one ton of farmyard manure would be worth, in round numbers, 15*s.* However, good dung can be bought in many places at 5*s.* per ton, or one-third its estimated money value; and practically the highest price which a farmer can afford to pay for good dung, if he has to cart it even a few miles, would not exceed 7*s.* 6*d.* per ton, one half its estimated money value. The difference between the estimated money value of farmyard manure (calculated at the market rate of the constituents, when sold as concentrated artificial manures), and the actual market price, may be fairly taken to represent the difference in practical value caused by the greater expense of the carriage and application of farmyard manure, and the less vigorous action of organic nitrogenous compounds as compared with ammonia salts.

In estimating the commercial value of sewage and night-soil manure, the calculated value of which does not exceed 1*l.* 1*s.* per ton, precisely the same circumstances have to be taken into account, which affect so largely the market value of ordinary farmyard manure. Accordingly the price which the farmer can afford to pay for the sewage and night-soil manures, analysed by me, or their real money value, will be only from one third to one half that of the calculated estimates given on the basis of their analyses.

The following table shows the market price or real money value of the various sewage and night-soil manures, samples of which were submitted to me for analysis :—

PRACTICAL OR MARKET VALUE OF ONE TON OF THE TREATED SLUDGE.

		s.	*d.*		*s.*	*d.*
(1.)	Bolton sludge from the M. and C. sewage process	3	3	to	4	10
(2.)	The same sludge 15 per cent. of moisture -	7	0	,,	10	6
(3.)	Solids drained from sewage before the liming process, at Bradford - - -	3	8	,,	5	6
(4.)	The same with 15 per cent. of moisture -	6	5	,,	9	6
(5.)	Bradford Corporation Sewage Outfall Works. Sludge from drying pits without artificial heat - - - - - - -	1	6	,,	2	4
(6.)	The same dried with 15 per cent. of moisture -	6	8	,,	10	0
(7.)	Deposit from the sewage of Leeds treated by the A. B. C. process - - - - -	2	9	,,	4	2
(8.)	The same sludge with 15 per cent. of moisture	5	6	,,	8	4
(9.)	Manure produced by the General Sewage Manure Company at Coventry - -	5	6	,,	8	4
(10.)	Rochdale manure - - - -	5	4	,,	8	0
(11.)	Manure manufactured by the Goux Company at Halifax - - - - - -	5	10	,,	8	9

In my judgment this tabular statement fairly represents the money value of 11 different samples sent to me for analysis at the place where the manures were produced.

Some of the products are worth a good deal less than an equal weight of common dung, which fully explains the circumstance that most sewage manures find no ready sale, even at a low price, and that in many works such manures accumulate to an inconvenient extent.

Indeed comparatively few farmers are so situated that they can afford the expense of carting semi-dried sewage sludge containing from 60 to 70 per cent. of moisture from the works to their fields. The refusal to accept such sludge as a gift in not a few instances rather shows sound discrimination than ignorance on the part of the farmers.

(Signed) AUGUSTUS VOELCKER.

APPENDICES.

APPENDIX No. I.—SEWAGE FARMS.

Abstracts from these separate Reports of the different systems are given in our Report.

EDINBURGH.

The city of Edinburgh has a population of about 196,979, living in 10,559 houses, in which there are 41,615 separate dwellings on the "flat" system. The volume of sewage is about 5,900,000 gallons per day. Sewerage works have from time to time been carried out the old sewers being of rude construction in which sewage stagnates, hence its black and foul condition at the several outlets. Main-sewering is stated to have been commenced about the year 1778, and the system has been extended from time to time, especially in the New-town as it has increased, and works of a better class are still in progress. The oldest main-sewers are built of rough stone, with flat stone bottoms and stone covers, having a sectional area of 18 feet (6 feet by 3 feet); the cost of the older sewerage has been 69,000*l.* Since 1853 main-sewerage works have been greatly extended at a further cost of 80,000*l.* and in the valley of the water of Leith, a sewer has been constructed to intercept sewage and the refuse from paper and other mills, and pass the same by a cast-iron outlet-pipe (costing with the other works 85,000*l.*), into the Frith of Forth at "Black Rocks." These works serve for a population of about 100,000. The sewers of Edinburgh are not regularly flushed, and are not at present sufficiently ventilated; several springs were tapped during the execution of the main-sewerage works, the water being taken into the sewers, and it is estimated that the daily volume from this source is equal to about 40,000 gallons.

There are in Edinburgh at present many waterclosets, and in the older and more crowded parts of the city, 9 Macfarlane's latrines and 35 public privies; but the excreta and other refuse of the inhabitants in the Old-town are chiefly collected in pails or pans, placed in the living rooms; these receptacles are said to be taken down every morning into the streets, and their contents emptied into the corporation carts and

so removed. The waterclosets and latrines are connected with the sewers; the privies are emptied by men employed by the corporation. The annual gross cost of cleansing the city of this excremental matter and house refuse is 23,645*l.*, the corporation receiving 7,458*l.* for 36,637 tons, which is sold to farmers to be used as manure. The sewage is not treated by lime or by any other disinfectant, nor is it filtered, and by far the larger portions from the southern and western parts of the city flow into the Jordon, Broughton, and Lochrin burns, and from thence, unutilized, into the Frith of Forth.

The sewage of certain districts of the city has long been used in rough and rude irrigation, in some cases since 1760, the lands irrigated being known as the "Craigentinny meadows" which have an area of about 220 acres, "Lochend meadows" about 28 acres, "Lochrin-on-Dalry meadows" about 40 acres, and "Brigend and Cairntows meadows" about 35 acres, making a total of 323 acres. There are about 250 acres of the Craigentinny and Lochend meadows under sewage irrigation; of these 200 acres are permanent pasture grasses, and 50 acres Italian rye grass. About 2,500,000 gallons of crude sewage, every 24 hours, flows through the "Foul Burn" on to the meadows. The grass is sold by public roup at the beginning of April in each year in allotments of from half a statute acre to one acre in area, at prices varying from 20*l.* to 40*l.* per acre per annum; one allotment (acre) sold last year for 44*l.* 15*s.* The permanent grass is used for cow feeding and is bought by dairymen at Musselburgh, Portobello, Leith, and Edinburgh, who have to cut and remove it; this is done about four times in the season, and yields an aggregate crop of about 40 tons to the acre. The Italian rye grass is cut five times a year and produces occasionally 60 tons to the acre. The irrigation is carried on in the cheapest and rudest way by the owners of the land adjoining the streams into which the sewage flows; no cost having been incurred in providing permanent carriers of either wood, iron, stoneware, or brickwork. A considerable portion of the sewage is absorbed by the "sea sand" of which the irrigated meadows of Craigentinny farm is composed, and thus the soakage of sewage from this land into the "Frith of Forth" is only partially purified.

The area of the meadows under irrigation is not sufficient to utilize the whole of the sewage brought down by the "Foul Burn," consequently a greater extent of crop might be obtained if the sewage could be applied to other portions of the farm or to the adjoining lands.

The annual cost of applying the sewage and receipts for the produce are,—

Receipts.	£	Expenditure.	£
250 statue acres of grass at average of 30*l.* per acre	7,500	Wages of watermen three in summer and one in winter, and cost of cleaning out carriers - - -	180
		Estimated rent of land 250 acres at 2*l.* per annum * - - - -	500
		Balance - - -	6,820
	7,500		7,500

The effluent water was flowing into the "Frith of Forth" at the date of our visit in August 1875.

* This is a price far above its agricultural value without the sewage. See analysis by Dr. Voelcker.

If the 2,500,000 gallons of sewage were used in irrigation on these 250 acres of land, each acre would receive upwards of 16,000 tons in the year, and this, valued at 1*d.* per ton, would be worth 67*l.*

We have caused an analysis to be made by Dr. A. Voelcker, F.R.S., of the Craigentinny meadows soil, and the following is the result:

Results by Analysis of a Sample of Soil taken from the Craigentinny Meadows, Edinburgh.

Dried at 212 F. the soil contained in 100 parts:—

*Organic matter	1·60
Oxide of iron and alumina	1·04
Phosphoric acid	0·06
Sulphuric acid	traces
Lime	0·08
Magnesia	0·25
Potash	0·08
Soda	0·13
Chloride of sodium	0·02
Silica (as white fine sand)	96·80
	100·06
*Containing nitrogen	0·039
Equal to ammonia	0·047

This soil, it will be seen, contains but very little lime, potash, and phosphoric acid, and thus is poor in all the more valuable mineral soil constituents.

It contains in round numbers only $1\frac{1}{2}$ per cent. of organic matter in the perfectly dried soil, and in that state nearly 97 per cent. of fine white sand. The organic matter was present mainly in the shape of roots and vegetable fibres remaining in the land from the crops grown upon it. It is hardly necessary for me to state that the soil from the Craigentinny meadows, Edinburgh, analysed by me is one characterized by extreme natural sterility. The entire value is in the sewage, and the amount realised by the crop is about one halfpenny per ton, less the rent of the land and the cost of the labour.—See pages 78, 79, and 80 as to raw and effluent sewage.

BANBURY.

Population (about)	12,000
Rateable value	£34,104
Houses	3,485
Waterclosets	2,485
Cost of main sewers	£6,400
Cost of outlet works and laying out sewage farm	£5,500
Volume of sewage every 24 hours (gallons)	320,000
Cost of pumping sewage and working expenses of farm	£1,281
Amount received for produce	£1,451

Banbury.—This town of 12,000 inhabitants, living in 3,485 houses distributed over an area of 3,920 acres, and having a rateable value of 34,104*l.*, has finally adopted irrigation as a remedy for the pollution

caused to the River Cherwell by the unpurified sewage of the town flowing into it. The town was sewered in 1856, and 2,485 waterclosets were connected with the system; the main outfall being into the River Cherwell. In order to prevent the coarser suspended matters of the sewage from flowing direct into the river, subsidence-tanks were constructed, and through these tanks the sewage flowed before it reached the river, but this did not remove the soluble matters of the sewage, causing serious annoyance to Mr. John Spokes of Tyford, whose mill is on the Cherwell, about five miles below Banbury, he complained of the nuisance, and meeting with no redress, filed a bill in the Court of Chancery on the 20th June 1864, and on the hearing of the cause, the Vice-Chancellor, Sir W. Page Wood, issued an injunction to restrain the Banbury Local Board from causing or permitting the main sewers of the town and district to discharge the sewage into the Cherwell. The Local Board were advised "that the sewage should be treated by per-chloride of iron and caustic lime in the state of so-called 'milk,' and in the proportion of 20 grains of the former and 10 grains of the latter to every gallon of liquid sewage, and the treated sewage be allowed to flow slowly through the tanks to enable the mechanically suspended and chemically separated matters to be effectually deposited, and the supernatant liquid to pass off clear and nearly colourless; and they were advised that there would then be little likelihood of the sewage becoming again putrescent after its admission into the water of the flowing river." On receipt of this report the Local Board caused additional tanks to be built, so that the sewage after treatment might remain in nearly quiescent state for about four hours before it flowed into the river; and the above process recommended by Mr. T. Hawkesley and Dr. H. Letheby was carefully carried on for some time, but failed to purify the sewage, and the Court, on the application of the Plaintiff, issued an order of sequestration. The Local Board then, as better advised, took on lease, from 11th day of October 1866, for 28 years, a farm at Warkworth, of 138 acres, the soil being a stiff loam upon a clay subsoil and had it laid out to receive the sewage, but, owing to the configuration of the land, it had to be pumped to a height of 21 feet; and 320,000 gallons) has been daily pumped on to the land ever since the farm was laid out, in winter as well as in summer. Subsequently, the Local Board received sanction to pur chase the before-mentioned land and an additional area of 100 acres, making together 238 acres, costing the sum of 23,400*l*. There is storeage in the tanks at the pumping station for eight hours flow of sewage; these tanks are cleaned out every six weeks, and the refuse mixed with the dry house ashes and street sweepings, was formerly sold at 6*d*. per ton, but, in consequence of an accumulation of nearly 2,0C0 tons, and there being no sale for it, the refuse with the street sweepings are now allowed to be taken away from the depôt free of charge.

The privies are cleansed at the cost of the occupiers of the houses to which they belong.

The rainfall on the roofs and the surface of the streets flows into the sewage-drains, and thence to the outfall, and has to be pumped to the farm, except in heavy rainfall, and then the storm water flows by the storm-outlet into the Cherwell. The sewers are ventilated at present, partially and imperfectly, by down spouts from the roofs of houses, and also by a few grids on the surface of the street. The cost

of the main sewers was 6,400*l.*; of the tanks and buildings 1,500*l.*; and of pumping-station, rising-main and laying out farm 4,000*l.*

The accounts of the receipt and expenditure for the year 1875 are as follows:—

BANBURY LOCAL BOARD OF HEALTH SEWAGE FARM SALES, &c., 1875.

Name of Field and Date of Sale.		Description of Crop.	Quantity sold.		Product of Sales.			Amount per Acre.		
			Acres	Chains	£	s.	d.	£	s.	d.
Great between Brooks.										
April 30	1st cutting -	Rye grass	6	3	28	19	0	4	11	11
June 11	2nd ,,	,, ,,	5	9½	41	13	0	7	0	0
July 30	3rd ,,	,, ,,	5	9	42	16	0	7	5	1
September 17	4th ,,	,, ,,	5	7	11	18	0	2	1	9
					125	6	0	20	18	9
May 14	1st cutting -	,, ,,	8	2	41	18	0	5	2	2
June 25	2nd ,,	,, ,,	8	2	55	13	0	6	15	9
August 13	3rd ,,	,, ,,	7	3¾	39	18	0	5	8	2
October 8	4th ,,	,, ,,	5	9½	6	0	0	1	0	2
					143	9	0	18	6	3
West between Brooks.										
May 28	1st cutting -	,, ,,	6	8½	40	18	0	5	19	5
July 16	2nd	,, ,,	7	3½	37	9	0	5	1	10
September 3	3rd ,,	,, ,,	5	9¼	18	0	0	3	0	10
					96	7	0	14	2	1
October 22	- -	Mangold wurtzel	2	0	17	15	0	8	17	6
East between Brooks.										
October 22	- -	Mangold wurtzel	11	1¼	162	6	0	14	11	8
Horse Stub.										
August 13 -	- -	Wheat	8	5	102	0	0	12	0	0
,, 13 -	- -	Oats	8	7½	122	10	0	14	0	0
					224	10	0	26	0	0
Great Bolland.										
May 28	1st cutting -	Mowing grass	24	5	132	2	6	5	7	10
August 13	2nd ,, -	,, ,,	24	5	58	0	0	2	7	4
September 17	,, ,, -	Aftermath	24	5	12	5	0	0	10	0
					202	7	6	8	5	2
Little Bolland.										
May 28	1st cutting -	Mowing grass	13	0	79	12	6	6	2	6
August 13	2nd ,, -	,, ,,	13	0	40	12	6	3	2	6
September 17	,, ,, -	Aftermath	13	0	14	19	0	1	3	0
					135	4	0	10	8	0

Name of Field and Date of Sale.	Description of Crop.	Quantity sold.		Product of Sales.			Amount per Acre.		
		Acres	Chains	£	s.	d.	£	s.	d.
Upper Plain.									
May 28 1st cutting -	Mowing grass	14	0	75	5	0	5	7	6
August 13 2nd „ -	„ „	14	0	28	0	0	2	0	0
September 17 „ „ -	Aftermath	14	0	11	14	0	0	16	0
				114	19	0	8	3	6
Middle Plain.									
May 28 1st cutting	Mowing grass	13	5	62	8	9	4	12	6
August 13 2nd „ -	„ „	13	5	27	0	0	2	0	0
October - - -	Aftermath	13	5	6	10	0	0	9	7
				95	18	9	7	2	1
Lower Plain.									
May 28 1st cutting -	Mowing grass	12	5	57	16	3	4	12	6
September 3 2nd „ -	„ „	12	5	22	10	0	1	16	0
„ 17 - -	Aftermath	12	5	5	12	6	0	9	0
				85	18	9	6	17	6
Right of shooting for the season - - -				4	0	0			
Keep of four horses - - - - -				43	8	0			
		Total £		1450	19	0			

The whole of the crops are sold standing, the Board being at no expense of cutting or carting.

Receipts. SUMMARY. Expenditure.

—	Area. A. C.	Product of sales.	Average per acre.	—	
		£ s. d.	£ s. d.		£ s. d.
Permanent pasture -	77 5	633 18 0	8 3 7	Rent (less Property tax) - - -	622 0 0
Rye grass (including horse keep).	24 4½	408 10 0	16 14 2	Rates and taxes - - - - -	39 12 5
				Superintendence and manual labour (including engine driver).	247 14 8
Wheat - -	8 5	102 0 0	12 0 0		
Oats - - - -	8 7½	122 10 0	14 0 0	Oil seed, &c. - - - - -	76 7 3
Mangold wurtzel -	13 1¼	180 1 0	13 14 4	Coal - - - - - - -	147 4 5
Right of shooting -	—	4 0 0	—	Own horse labour (about) - - -	30 0 0
				Manager's salary - - - -	45 0 0
	132 3¼	1450 19 0	—	Commission, &c. - - - -	72 11 0
Total area of farm (including roads).	A. R. P. 138 0 38	1450 19 0	10 9 11		£1,280 9 9

Mr. Thomas Garrett, the town surveyor and manager of the farm, has been successful in carrying off several silver cups and money prizes for the roots grown by sewage of the farm.

NOTE.—See pages 87 and 88.

BEDFORD.

Population (about)		18,000
Rateable value		£65,000
Houses		3,500
Waterclosets		3,000
Cost of main sewers		£19,000
Cost of outlet works, pumping station, and laying out sewage farm		£9,200
Volume of sewage every 24 hours	(gallons)	700,000
Rent, labour, and expense of working farm		£3,280
Amount received for produce		£3,461

Bedford. This is an instance of a town which, without being forced by the expensive machinery of the Court of Chancery to get rid of the nuisance caused to the river by sewage pollution, has endeavoured to utilize its sewage by applying it to profitable use in irrigation. The Local Board District of Bedford has an area of 2,200 acres, and a rateable value of 65,000*l.*, with a population of about 18,000 living in 3,500 houses, to which are attached at least 3,000 waterclosets, and as there are no privies, this may truly be termed a watercloset town. A thorough system of sewerage has been carried out, commenced in 1864 and finished in 1868 at a cost of 19,000*l.* The old sewers are used as surface and storm-water conduits, and these have three outlets into the river Ouse. The whole of the sewage proper is intercepted from the river by the new sewers, and gravitates to a point at Newnham, about a mile from the town, where it flows into a sewage-well, and is thence pumped on to 155 acres of land, a small portion of which is the property of the corporation. The larger part is leased from the Duke of Bedford, the Rev. J. W. C. Campion, and Captain Polhill Turner. The soil of the farm is a rich loam with a gravelly sub-soil, well adapted for the purpose to which it is devoted, and the surface has been especially laid out for irrigation. The permanent carriers are stone-ware pipes, with side-junctions at proper intervals for regulating the flow of sewage on to the plots of land required to be irrigated. The volume of sewage which has to be pumped, is estimated at 700,000 gallons every 24 hours, but of this 300,000 gallons is sub-soil water. The main outfall sewer is 5 feet 3 inches by 3 feet 9 inches in sectional area, three quarters of a mile long; is laid at a gradient of 1 in 3,520, and serves as a storage-tank. The sewage-well, at the pumping-station, is of small capacity, and to prevent choking the pumps by the coarser particles of sewage, the suction-pipe is protected by iron screens.

The outfall-sewer is cleaned out occasionally, and the deposit which is little more than detritus is carted away.

The cost of preparing the land, constructing carriers, erecting pumping station, and fitting it with machinery was 7,200*l.*

By the courtesy of the town clerk we are enabled to give a copy of the General Account and Balance Sheet for the year ended 31st December 1874, and also proceeds from sales of crops for the year ended 31st December 1875.

The Urban Sanitary Authority for the Borough of Bedford.—Irrigation Farm.—General Account and Balance Sheet at Stock-taking 31st December 1874.

Dr.

	£	s.	d.	£	s.	d.
Stock, December 1873 -	431	0	0			
Working plant, Dec. 1873	222	4	0			
				653	4	0
Labour, manager, and engineer -				667	17	2
Trademen's bills, &c. - -				780	10	9
Rent - - - - - -				917	4	0
Rates and taxes - - -				113	14	7
Permanent works - - -				24	2	8
Oats - - - - - -				16	5	0
Hay - - -	48	2	6			
Beans - - -	59	10	0			
				107	12	6
Balance for 1874 - -				180	15	4
				£3,461	6	0

Cr.

	£	s.	d.	£	s.	d.
Sale of Crops - - - - -				2515	13	10
Stock in hand and purchased, 1874 -				544	8	0
Working Plant and Live and Dead Stock.				269	9	0
Sewage Works - - - -				24	2	8
Hay - - -	48	2	6			
Beans - - -	59	10	0			
				107	12	6
				£3,461	6	0

Corn &c., for live stock.—

	£	s.	d.
Corn purchased, (see expenditure) - - - -	40	8	9
Hay from farm - - - - - - - -	48	2	6
Oats - - - - - - - - -	16	5	0
Beans - - - - - - - - -	59	10	0
	£164	6	3

	£	s.	d.
Labour - - - - -	492	9	7
Manager - - - - -	112	11	1
Engineer - - - - -	62	16	6
	£667	17	2

	£	s.	d.
Tradesmen's bills paid - -	79	11	7
Tradesmen's bills owing - -	30	10	2
Coals - - - - - -	260	2	7
Coals owing - - - - -	32	8	0
Horse corn, &c. - - -	40	8	9
Manure purchased - - -	10	0	0
Horse and bullocks purchased -	133	10	0
Seeds - - - - - -	102	8	4
Hire of Horses for ploughing -	30	3	0
Mr. Stafford's commission and expenses.	114	12	6
	833	14	11
Deduct bills owing 1873 -	53	4	2
	£780	10	9

Rents—

	£	s.	d.
The Rev. Campion - -	126	14	11
Captain Polhill Turner - -	421	11	3
Duke of Bedford - - -	244	8	2
Corporation of Bedford - -	123	9	8
L. & N. W. Ry.—Sewer under railway.	1	0	0
	£917	4	0

	£	s.	d.
Poor Rates - - - - -	92	0	3
Income Tax - - - - -	18	3	2
Land Tax - - - - -	3	1	2
Insurance - - - - -	0	10	0
	£113	14	7

	£	s.	d.
Permanent works - - - -	24	2	8

	£	s.	d.
By Sale of Crops, Mr. Stafford -	1,933	1	1
Manager - - - - -	582	12	1
	£2,515	13	10

Stock in hand and purchased, 1874—

	£	s.	d.
30 tons of hay, 5*l.* - - -	150	0	0
26 loads of beans, 28/- - -	38	8	0
2 acres of mangolds, 20*l.* - -	40	0	0
6 tons of potatoes, 4*l.* - -	24	0	0
16 acres of growing wheat, 50/-	40	0	0
Bean, barley, and oat straw -	15	0	0
Rye grass hay - - -	10	0	0
Pickling cabbages - -	12	0	3
Carrots - - - - -	25	0	0
12½ oats, 26/- per qr. - -	16	5	0
6 acres of growing cabbage, 5*l.* -	30	0	0
9½ acres of growing rye grass, 50/	23	15	0
8 bullocks, 15*l.* - - -	120	0	0
	£544	8	0

Working plant and live and dead stock.

	£	s.	d.
4 horses - - - -	175	0	0
3 carts, 8*l.* - - - -	24	0	0
1 horse roll - - - -	7	10	0
1 double plough - - -	3	0	0
1 single ditto - - -	1	10	0
1 horse hoe - - -	4	0	0
1 scuffler - - - -	4	0	0
2 sets of harrows - - -	2	0	0
1 pulper - - - -	2	10	0
1 chaff cutter - - -	4	0	0
1 bean mill - - -	2	10	0
6 wheelbarrows - - -	1	4	0
4 sets of Harness - - -	6	0	0
1 cultivator - - -	2	15	0
3 cow cribs - - -	3	0	0
Office furniture - - -	2	10	0
Coals in stock - - -	24	0	0
	£269	9	0

J. E. Cutcliffe,
W. Roff,
Harry Thody,
Thomas Hall Barkham,
Jas. Thos. Hobson,
} Farming Committee.

Borough of Bedford. Urban Sanitary Authority Irrigation Farm.

Account of Proceeds from Sales of Crops, year ending 31*st December* 1875.

—	Area under cultivation.			Amount.		
	A.	R.	P.	£	*s.*	*d.*
Italian rye grass	22	0	0	399	0	6
Potatoes	25	1	0	140	16	6
Mangolds	40	2	20	599	6	6
Onions	10	0	20	287	0	0
Carrots	7	3	0	116	1	0
Cucumbers	1	0	0	16	1	0
Vegetable marrows	0	0	10	1	6	3
Asparagus	0	0	20	2	11	0
Rhubarb	0	0	20	5	0	0
Cabbage	6	1	10	87	12	0
Pickling cabbage	1	1	0	34	18	8
Cauliflowers	6	0	0	60	0	0
Oats	14	0	0	135	0	0
Wheat	16	1	10	228	13	9
Permanent pasture	30	0	0	181	10	6
	180	3	30	£2,294	17	8

Note.—See pages 91, 92, 93, as to raw and effluent sewage.

BLACKBURN.

Population (about)	90,000
Rateable value	£235,127
Houses	16,700
Waterclosets	730
Volume of sewage every 24 hours (gallons)	1,500,000
Privies and middens	10,574
Privies, "pail" system	2,690
Ashpits	5,287
Yearly cost of cleansing privies on both systems	£5,641
Amount received for refuse	£1,806

The rateable value of *Blackburn* is 235,127*l.*, and a population of about 90,000 is here grouped together in 16,700 houses on an area of 3,620 acres. There are at present only 730 waterclosets in the borough, and the fæcal waste of the inhabitants is therefore principally disposed of by 10,574 of the "old Lancashire middens," and by 2,690 privies of more modern construction on the "pail" system; there are also 5,287 ashpits for collecting this form of house waste.

The borough has been sewered; the works were commenced in 1850, and finished in 1873, at a cost, including subsidence-tanks, of 78,245*l.*

The old drains have been utilized to convey the rainfall off roads and streets by 10 outlets into the river; whereas, the new drains are used for the sewage proper, and as all the old middens are drained into the new sewers, the composition of the sewage of Blackburn is very similar to that discharged from an entirely water-closeted town, the proportion of putrescible organic matter in solution in the sewage being slightly less, whilst the organic matter in suspension is somewhat greater.

The Rivers Pollution Commissioners caused numerous samples of the sewage of both midden towns and watercloset towns to be analysed in their laboratory, and from the results of these analyses, they were enabled to say:—"The retention of the solid excrements in 'middens' is not therefore attended with any considerable diminution in the strength of the sewage, although the volume even in manufacturing towns is somewhat reduced. It seems hopeless, therefore, to anticipate any substantial reduction of sewage pollution by dealing with solid excrementitious matters only."

In 1865 the main outfall sewer discharged direct into the "Blakewater," and caused serious pollution, not only to that river, but also to the Darwen into which the Blakewater emptied; the nuisance was complained of by the riparian owners, and a Bill was filed in the Court of Chancery by Sir William Fielden, Bart. (of Feniscowles), praying that the corporation might be restrained from polluting the river Darwen with the sewage of Blackburn, and an injunction was granted.

The defendants applied for time to enable them to cause remedial works to be constructed, and the Court gave the time asked for. The corporation then directed subsidence tanks to be built near the river Blakewater on the eastern boundary of the town, and caused the sewage to flow through these tanks and to be treated by the "lime-process" (*i.e.*, adding a certain proportion of "milk of lime" to facilitate deposition) before the sewage entered the river; but this did not sufficiently mitigate the nuisance, and although the supernatant liquid flowed off comparatively clear, the method failed to purify the sewage so as to render it admissible into the river, for at a short distance from the outlet of the sewage-tanks the river was still in a most offensive condition of putrefaction. The plaintiff then brought an action in the Court of Queen's Bench and laid the damages at 20,000*l.*; the case came on for trial and was referred to Mr. Manisty, Q.C., who found for the plaintiff, but only awarded to him 1,250*l.* damages, and costs; the cost of the suit in Chancery and the damages and costs in the action at law amounted however to about 12,000*l.*

The corporation then, as advised, determined to adopt sewage irrigation, and for this purpose promoted a Bill of Parliament in the session of 1870; there was great opposition to this Bill, but it was passed and it empowered the corporation to acquire 1,090 acres of land, in the townships of Pleasington, Houghton, and Samlesbury. The cost of obtaining the Act was 6,500*l.* In 1872 the corporation took on a lease, for 20 years, at the yearly rent of 484*l.* 179 acres of land in the townships of Pleasington and Houghton, and directed the outfall sewer to be extended to Higher Park, Pleasington, and 90 acres of the 179 acres, upon which the sewage would gravitate, to be drained and especially laid out to receive it. The works have been carried out a cost of 11,600*l.*, and about 1,500,000 gallons of sewage every 24 hours have flowed on to the farm, and have been used in irrigation ever since the works were completed. The 90 acres have been cropped this year (1875) 74 acres with Italian rye grass, and 10 acres with mangolds and turnips, whilst the remaining six acres of the land were in fallow and roads. In order to dispose of the produce without loss, the corporation purchased stock. The total expenditure for the year ended 31st December 1875, including working expenses, purchase of stock, and also a sum of 480*l.*, the cost of permanent improvements, was 6,523*l.* 2*s.* 9*d.*, and the receipts for the same period, including sale of fat stock, were 5,781*l.* 6*s.*, 10*d.* It is believed that this year (1876) the receipts will more than cover the expenses.

In order to extend their irrigation the corporation, in 1875, concluded

the purchase of 475 acres of land at Samlesbury, at a cost of 69,500*l.*, including expenses of arbitration, easements, &c., being at a rate of about 100 years purchase of the present rents, and they have directed their engineer to extend the sewage conduit on to this newly acquired land at an estimated cost of 7,650*l.*, to which the cost of draining and preparing the land must be added. The farm at Pleasington and Houghton has a light loamy soil upon a gravelly subsoil; it has been under drained to a depth of 4 feet, the drains being 18 feet apart. It is intended to drain the land at Samlesbury, which is partly loam and partly stiff clay.

In addition to the cost of disposing of the sewage in irrigation, there is the cost of cleansing the "middens" and the privies on the "pail" system; this amounts to 5,641*l.* 2*s.* 8*d.* yearly, and the annual receipts for the refuse from both kinds of privies is only 1,805*l.* 12*s.* 5*d.*

CHELTENHAM.

Population (about) - - - - - - -	45,000
Rateable value - - - - - - -	£217,849
Houses - - - - - - - -	8,725
Waterclosets - - - - - - -	8,500
Cost of outfall works, purchase and laying out of farm -	£18,000
Volume of sewage every 24 hours - - (gallons)	1,250,000

Privies are cleansed at the expense of the occupiers of the houses to which they belong.

Cheltenham.—The sewage of this township, which has an area of about 2,000 acres and a resident population, including portions of Charlton-Kings, Leckampton, and Prestbury, of about 45,000, living in 8,725 houses, and a rateable value of 217,849*l.*, is disposed of in irrigation. The natural drainage of the district is into three streams flowing from east to west, *i.e.*, Wyman's Brook on the north, the Chelt in the centre, and the Hatherley Brook to the south; all the sewage, however, runs towards the Chelt and the Hatherley Brook, near which streams the subsidence-tanks have been constructed, from which it flows, by gravitation through earthenware pipes to the farm. The local authority have in contemplation to conduct by pipes in a northerly direction a portion of the sewage from the tank near the Chelt on to land in the parish of Elmstone-Hardwicke, abutting on Wyman's Brook, and if the proposal be carried out, a great object will be obtained in bringing under sewage irrigation an extended area of land admirably adapted for the purpose; and as the owner and tenant of the land are willing to join in an agreement for 14 years, a degree of permanence will be assured; the tenant will take the responsibility of dealing with the sewage on his own land so as not to occasion nuisance or injury to others; he will also pay a fair rent for it. The watercloset system is generally adopted, there being about 8,500 in the town. The average volume of sewage every 24 hours is 1,250,000 gallons, and as stated above, this flows from the main outfall-sewer into subsidence-tanks, which are constructed with transverse divisions to intercept matters in suspension, and by an arrangement the sewage as it flows through the tanks works a turbine and chain pump; by this means the "sludge" is pumped up, and mixed with the house refuse and ashes, (about

3,234 cubic yards). There is no permanent accumulation of this refuse. The cost of cleansing the tanks and the receipts for the last three years are—

Year.	Cost of cleansing tanks and incidental works thereto.	Receipts for sale of sludge, mixed with ashes, from domestic fires.
	£ *s.* *d.*	£ *s.* *d.*
1873	237 9 8	293 7 4
1874	278 0 2	271 16 0
1875	296 6 1	347 5 0

Before irrigation was adopted, proceedings were threatened against the Improvement Commissioners, but no action arose, and in 1870 they purchased a farm of 131 acres (6 acres arable and 125 acres in permanent pasture) at Boddington on the western side of the town, and distant therefrom about two miles; the soil is a stiff clay, and the land has a gentle slope from east to west. The sewage is delivered by the earthenware conduit from the tanks on to the high part of the farm, it is occasionally applied to 200 acres of land adjacent to the conduit, for which the tenants pay to the Improvement Commissioners 7*s.* per acre for each dressing of sewage, amounting last year to the sum of 156*l.* The whole of the land at the farm, with a trifling exception, can be irrigated from the summit; there are various branch-pipes for the delivery of the sewage to different parts, and these branches are to a great extent laid in cuttings of a moderate depth, open-carriers having been found objectionable as the cattle trod them out of form, the land being grazed during the greater part of the year. The undulating form of the land, and the arrangement of the branch conduits at different levels afford facilities for passing the sewage again over the lower portion of the farm when it has been over the higher portion of it, and thus is insured more perfect purification of the water before it flows into the Chelt and Hatherley Brook. The sewage-farm has been let at a yearly rent varying from 815*l.* to 861*l.*, and is now let at a rent of 800*l.* per annum, subject to the Improvement Commissioners undertaking the duty of applying the sewage, at a cost in labour of 150*l.* a year, to which must be added the amount of rates and taxes which they also pay of about 50*l.* a year. There are only three residences, two homesteads, and about 20 scattered cottages near the farm. Previous to the adoption of irrigation, a process of treating the sewage by lime, per-chloride of iron and Bird's powder was tried, but the result was unsatisfactory. No complaint has ever been substantiated since the adoption of irrigation, and there is not now, even in hot summer weather, any nuisance caused by the effluent from the sewage farm. The cost of the sewerage works has been to the present time 53,400*l.*, including purchase and laying out of farm and building tanks.

CHORLEY.

Population (about) - - - - - - -		20,000
Rateable value - - - - - - -		£54,407
Houses - - - - - - - -		4,000
Waterclosets - - - - - - -		200
Cost of outlet works, purchase, and laying out farms at Common Bank and Plymouth Bridge - - -		£16,550
Volume of sewage every 24 hours - -	(gallons)	500,000
Privies and middens - - - - -		1,600
Privies, "pail" system - - - - -		700
Cost of cleansing privies on both systems - -		£709
Amount received for refuse - - - -		£186

Chorley (*Lancashire*).—Area of the district 3,613 acres, population about 20,000; annual rateable value, 54,407*l.* There are about 4,000 houses, 200 waterclosets, and 1,600 privies, but these latter are being gradually abolished and the "pail" system introduced, and about 700 privies are now reconstructed on this system. The district, with the exception of a small area at Cowling and Botany, was sewered in 1855, at a cost of 17,000*l.*, and the sewage then gravitated to one outfall in the river Chor. Complaints were repeatedly made to the Improvement Commissioners by the Reverend J. Sparkling, Mr. Henry Alison, Mr. R. Townley Parker, Mr. E. E. Silvester, and Mr. Randolphus de Trafford, riparian owners, of the nuisance caused by the sewage of the town being discharged into the river Chor and thence carried down into the river Yarrow, which polluted and rendered offensive the water of the Yarrow from the confluence of the Chor to below the village of Croston, and in July 1867 Mr. Edward Silvester and Mr. Henry Alison filed a bill of complaint in Chancery and prayed, "That the "defendants be restrained by injunction from causing or allowing the "sewage to be discharged, or to flow into the river Yarrow so as to be "a nuisance and pollute the said river." The defendants (the Chorley Commissioners) by their counsel admitted that the discharge of sewage into the Yarrow, by means of the Chor, had polluted the river, and that the works constructed by them had become a nuisance. A perpetual injunction was issued to restrain the defendants from continuing the same, such injunction not to take effect until the expiration of 12 months from the date of the decree, 23rd November 1867, or until the expiration of such further period as the Court should from time to time direct. With the intention of diverting the sewage from the Chor and Yarrow and utilizing it in irrigation the Improvement Commissioners, on the 21st October 1867, took on lease for 21 years, at a yearly rent of 130*l.*, a farm of 87 acres, at "Common Bank," about a mile to the West of Chorley, and subsequently, in 1870, purchased it for 6,450*l.*, and caused it to be laid out to receive sewage. The outfall-sewer was extended and continued on to the farm by cast-iron pipes; permanent carriers to distribute the sewage were also constructed of brickwork, stoneware-pipes and wood; and suitable farm buildings, were also erected; these works cost 4,800*l.* As soon as the works were completed, the sewage, which is estimated to be about 500,000 gallons every 24 hours, 200,000 of this being subsoil water, flowed continuously over the farm. The land, which is for the most part poor vegetable soil, with a stiff clay subsoil, has been underdrained to

a depth of 3 feet 6 inches, the drains being 16 feet apart. The local authority obtained power in 1871 to acquire additional land for the purpose of sewage utilization, and in 1875 purchased and laid out an area of 46 acres, part of "Kingsley's farm," at Plymouth Bridge, at a cost of 5,300*l.*; this land has a clay subsoil, and is arranged for the purpose of receiving the sewage of the Chorley Moor district. The Improvement Commissioners have since let this land with the sewage, at an annual rent of 90*l.*, the tenant undertaking to distribute and cleanse the sewage, so as not to cause a nuisance.

The sewers are ventilated by 120 open grids, in the surface of the streets near the manholes, by rain-water pipes from the eaves of buildings, by pipes carried up at the gable ends of buildings, and by connexion with the chimney-shaft of the Water Street mill. No complaint has been made of the state of the purified effluent water flowing from the sewage farm into the Yarrow.

The working of the "pail" system is an annual loss, costing more than cleansing privies and middens, but it is believed that the removal, once a week, of the excreta under the "pail" system, will improve the health of the inhabitants. The expense of cleansing the privies, and "pails" for the year ended 31st May 1875, was 708*l.* 15*s.* 4*d.*, and the receipts for the refuse were 186*l.* 3*s.*

The sewage farm was cropped in 1875, with oats 20 acres, Italian rye grass 20 acres, wheat 3 acres, Swedes 7 acres, while of permanent pasture and meadow there were 39 acres, and osiers 1 acre. The meadow land produced two tons of hay per acre, which sold at 7*l.* per ton; the Italian rye grass, in four cuttings, 10 tons per acre, and realized 16*s.* 8*d.* per ton; the oats yielded 50 bushels and 2 tons of straw per acre sold for 3*s.* 6*d.* per bushel and 70*s.* per ton; the swedes 15 tons per acre, and sold for 1*l.* per ton, and the 1 acre of osier realized 11*l.* There is a dairy of 11 cows kept on the farm; there are also 2 bullocks 24 young stock, and 5 pigs feeding. The farm is worked by 3 horses.

DONCASTER.

Population about 20,000.

Waterclosets are not generally used.

The town is sewered, and the houses are drained.

The volume of sewage flowing to the sewage pumps is about 600,000 gallons per day; or about 219,000,000 gallons per annum.

Flood-water from the surface of the town overflows to the rivers.

The 600,000 gallons of sewage is pumped daily on to the land of the Sewage Farm.

The works to store and pump the sewage have cost 20,000*l.*

The lift is 52 feet.

The Sewage Farm is 264 statute acres of light sandy land.

The rent was 25*s.* per statute acre.

The corporation pump the sewage, and obtain a rental of 800*l.* per annum, or about 3*l.* per acre.

The land has been three years under sewage cultivation; but only about 115 acres have received dressings of sewage in this time.

The entire pumping of one day, 600,000 gallons, has been disposed of over one acre.

The usual course is to distribute this volume of sewage over 5 acres.

Italian rye grass has received per acre in one year at a rate of 13,000 tons, or a vertical depth of sewage of 130 inches. The land during the season would readily have disposed of double this volume of sewage, 260 inches,—if it had been desirable so to dispose of it. The 130 inches were actually required by the grass.

Doncaster.—This borough has an area of 1,690 acres, a population of about 20,000, and a rateable value of 68,721*l*. 10*s*. There are in the borough 4,300 inhabited houses ; the existing water supply is defective, consequently waterclosets are not generally used. The town has been sewered, but not more than one half of the excreta of the inhabitants flows to the pumping-station at the outfall-works. The main-sewers are of brickwork, and the branch mains of sanitary pipes. The sewers are ventilated by means of open grids in the covers of manholes at the street surface ; and, in some instances, by pipes carried up the gable ends of the houses above the roofs. The sewerage works were completed in 1870, under the advice and superintendence of Mr. B. S. Brundell, C.E., and the sewage then flowed by an existing outlet into the river Don navigation. The proprietors of that navigation, in the autumn of 1870, filed a Bill of Complaint in Chancery, and obtained an injunction. The corporation, as advised, not having a defence, consented thereto, asked for time to be given in which to carry out remedial works, and the Court granted two years. The corporation then directed Mr. Brundell to examine and report on the best means of disposing of the sewage. This he did, and reported in favour of irrigation, advising that the sewage should be intercepted from the river and pumped on to land, the property of the Corporation at Long Sandall. Subsequently, the works, as designed, were carried out, at a cost, of 20,000*l*. The whole of the sewage of Doncaster, with the exception of that part of the town known as Bennetthorpe, consisting of about 80 houses, gravitates to a point on the north side of the town, and flows into a sewage-well, first passing through iron screens fixed across the well to prevent choking of the pumps by cotton-waste, rags, and shavings thrown into the sewers. A volume of crude-sewage, varying from 500,000 to 800,000, or an average of 600,000 gallons, is pumped daily from 6 a.m. to 11 a.m., and from 1 p.m. to 5.30 p.m. The outfall-sewer is of sufficient capacity (6 feet in diameter) to hold the dry-weather sewage flowing during the night; but in wet weather the sewage can be pumped, at night, into a tank on the farm, capable of holding 1,000,000 gallons. There is also a storm-outlet, by which the sewage, when extremely diluted by heavy rain-fall, can be pumped direct into the "flood drain." The sewage-farm is on the road leading to Thorne, on the north side of, and about two miles from, Doncaster ; the corporation are owners of a considerable estate in this neighbourhood, and the "Wheatly Hills Farm," of 264 acres of land (partly light open soil and partly clay) has been laid out as a sewage-farm, and has been let with the sewage, together with a suitable house and farm buildings, on lease for 14 years, at a yearly rent of 800*l*., the corporation undertaking to pump and deliver the sewage of Doncaster on to the farm at the yearly cost of about 300*l*. The clay-land is underdrained ; but the light open land is only underdrained in the valleys and low places, and it is found that the purified drainage water finds its way readily through the light soil from long distances to these subsoil drains. There are five acres of land, especially laid out, and deep under-drained, which can be used as a filter on the "Downward Intermittent" principle, as proposed by the Rivers Pollution Commission. Up to the present time, how-

ever, the sewage has been utilised, and it has not as yet been found necessary to use the "filter" as an auxiliary to the irrigation process. The Sewage-Farm has now been in operation three years, no nuisance having arisen either at the pumping-station or on the farm. The distribution of the sewage over the land is judiciously managed, as none of it is allowed to stagnate, and thereby cause nuisance, and destroy the crop. The whole of the sewage of the night and following morning is pumped on to the farm by 11 o'clock in the forenoon, and the longest period during which the sewage is allowed to be at rest in the main outfall-sewer is between 6 p.m. and 6 a.m.

The crops grown this year (1875) to which the sewage has been applied, are: beans, 13 acres; peas, 6 acres; oats, 7 acres; barley, 35 acres; wheat, 51 acres; Italian rye grass, 35 acres; mangolds, 34 acres; swedes, 16 acres; potatoes, 8 acres; white turnips, 6 acres; hay, from permanent grass, 7 acres; permanent grass fed off, 22 acres; market garden produce, 12 acres; and there were also in fallow 8 acres.

The bean crop was a good one; the pea crop, which was partly good, and sold green, produced 10*l.* 10*s.* 0*d.* per acre; the oats were light, owing to the drought in March, April, and May; the wheat made excellent straw, but the crop was damaged by the heavy rain in June and July, and gave only an average yield; the four cuttings of Italian rye grass produced 30 tons to the acre, and sold for 16*s.* 8*d.* per ton; the mangolds were, owing to the drought and deficiency of sewage, late in starting, but as soon as the sewage was applied they grew well, but did not, however, produce more than 26 tons to the acre, and sold on the ground for 15*l.* 15*s.* 0*d.* per acre, the buyer to "pull and lead off;" the swedes also only yielded a light crop, and sold for 7*l.* 10*s.* 0*d.* per acre; the potatoes gave a good crop, and sold for 20*l.* an acre, the buyer to get and cart them off the farm; the market garden produced very excellent crops, which commanded good prices, and were highly successful, especially that portion (3 acres) planted with fruit trees, the currants being exceedingly fine.

In addition to the waterclosets in use in the borough, there are 2,553 ashpits, having privies connected with them, and 525 separate ashpits; these are emptied by scavengers employed by the corporation, at a yearly cost of 539*l.*, and 310*l.* is received for 4,400 tons of refuse removed yearly, and sold to farmers in the neighbourhood, who use it as manure.

Particulars of Machinery.

Power of Engine and Sort of Engine.

Two compound beam engines, of 35 nominal horse power each with crank and fly-wheel; slide-valves worked by eccentrics; double expansion slides on high-pressure cylinder.

Cost of Engine and Boilers complete.

5,405*l.* Cannot give engines and boilers separately.

Gallons per hour lifted.

80,000 gallons (7th April 1873).

Head.

Nett, *including* friction, 56·5 feet.

Fuel Consumed.

(Coal; inferior Barnsley, somewhat weathered in trial (7th April 1873). 107 lbs. per hour.

Diameter of Pump.
Double acting; 20 inches diameter.

Length of Stroke of Engine.
Low-pressure cylinder, 4′ 6″ stroke.
High-pressure do. 3′ 1½″ do.

Number of Strokes per Minute.
22 revolutions.

TRIAL of one ENGINE for One Week, from 23rd February 1874 to 1st March 1874.

Time of pumping, 45¾ hours.
Coal consumed, 3 tons = 147 lbs. per hour of actual pumping.
Number of stoppages, 11.
Gallons pumped, 3,843,000.
Tons pumped, 17,156¼ = 375 tons per hour.

HARROGATE.

Population (average)	- - - - -	12,000
Rateable value	- - - - - -	£50,000
Houses	- - - - - - -	1,500
Waterclosets	- - - - - -	1,620
Cost of main sewers	- - - - -	£15,583
Cost of outlet works and laying out land at Jenny Plain	-	£1,150
Purchase of land at outlet works at Wetherby Lane	-	£4,484

Harrogate.—This is essentially a water-closeted town; the area of the district is about 1,300 acres. Resident population, about 8,000, augmented in the season, from the months of May to October, to about 16,000; the annual rateable value is 50,000*l*. There are 1,500 inhabited houses, and 1,620 waterclosets in the township, and very few common privies. The waterworks belong to a private company. The "Coppice" stream, a tributary of the "Oak Beck," flows through the town, and that portion of the river-channel in the town has been covered over; into this stream several of the old sewers discharge. In 1867 complaint was made by a bleacher (Mr. Wood, of Rawden, near Leeds), whose bleachfields are on the "Oak Beck," of the fouling of the stream by the sewage of the township, and proceedings at law were threatened. The Improvement Commissioners compromised the matter by paying 580*l*., undertaking "*not to discharge any more sewage into the stream.*" In order to give effect to this agreement, they directed their surveyor to prepare plans of main sewerage works for the township; these works were, in 1869, carried out at a cost of 15,583*l*., and to cleanse the daily and nightly volume of sewage, which is estimated at about 168,000 gallons (inclusive of about 83,000 gallons of spring water), the Improvement Commissioners obtained a lease of 47 acres of land, a stiff clay soil at Jenny Plain, one mile from the town. This land they caused to be specially laid out, and subsidence-tanks to be constructed into which the outfall-sewer should discharge, the sewage to flow from thence through stoneware pipe carriers on to the land, and the effluent water run off into the "Oak Beck." The cost of these works was 1,150*l*. In April 1869, about two months after receiving the 580*l*.,

and while the works of sewerage and irrigation were in progress, Mr. Wood commenced a suit in Chancery against the Improvement Commissioners, and in January 1875 obtained an injunction to restrain them from polluting the "Coppice" stream and "Oak Beck" with the sewage of the township. From the decree of Vice-Chancellor Bacon the Commissioners appealed, but the Lords Justices affirmed the decision of the Court below, and on application by the defendants the time for carrying out the remedial measures was extended to April 1st, 1875. In February 1875 additional intercepting sewers were commenced for diverting the sewage from the "Coppice Stream," and conveying it to the irrigation works, but it was found impossible to complete these works by the 1st of April 1875, and an application was made to the Court for a further extension of time, and it was extended to the 1st of July 1875. In June the Improvement Commissioners applied for a still further extension, but the Court refused to grant it. In April 1875, the Improvement Commissioners purchased, at a cost of 2,200*l.*, the Knox bleachfields, in the occupation of the plaintiff, Mr. Wood, subject to a lease he held for an unexpired term of four years, and on the 4th October 1875 they took on lease, for a term of 20 years, from the Ecclesiastical Commissioners, at the yearly rent of 300*l.*, a farm of 247 acres, for the purpose of further purifying the sewage. This farm (of which only 120 acres are available for sewage irrigation) is situated on the north side of the "Oak Beck," opposite to the present irrigation fields.

In December 1875, the Plaintiff applied to the Vice-Chancellor to issue an order of sequestration, this the Court did, but suspended the operation of it for two months. The Improvement Commissioners then directed their surveyor to prepare plans and estimates for a pipe sewer to intercept the effluent water from the irrigated fields and convey it into the "Oak Beck" at a point below the plaintiff's bleachfields, this having come to the knowledge of the plaintiff, he made overtures for a compromise, and after a conference with a deputation from the Improvement Commissioners he offered to withdraw from the suit, if they would pay to him the sum of 5,000*l.* and taxed costs; the Improvement Commissioners accepted his offer, but he subsequently varied it and asked for the whole of the costs "in and incidental to the suit;" this, however, the Improvement Commissioners declined to accept, and they have since directed their surveyor to continue the main outfall-sewer, by a syphon under the "Oak Beck," on to the new farm of 247 acres, and at once to lay out the land at an estimated cost of 3,216*l.*, to receive the sewage. It is hoped that the area proposed to be irrigated will be found sufficient to cleanse effectually the whole of the sewage of the district, and thus, the Commissioners will be enabled to obey the order of the Court. The cost of the suit amounted to about 3,920*l.* The subsidence-tanks are cleansed out of every three months, the deposit being mixed with the street sweepings and sold to farmers.

Upon the present sewage farm of 47 acres, there was grown, in 1875, 600 tons of Italian rye grass, and it sold for 10*s.* per ton. The cost of dealing with and distributing the sewage in 1874, including rent of land, was 282*l.* 10*s.* 5*d.*, exclusive of interest and cost of works, and the receipts for the grass were 562*l.* 11*s.* 1*d.*

The effluent water from the sewage farm was on our inspection clear and inoffensive; and the "Oak Beck," into which it flows has the external characteristics of a clean and pure stream, there being no appearances of sewage deposit on the banks or bed of the brook, and the vegetation on the margin of the stream being free from the peculiar brown fungoid growth the result of the presence of sewage.

To prevent the sewage of High Harrogate from polluting the watercourses which have their outfall in the "Nidd," the river from which the inhabitants of Knaresborough obtain their water-supply, the Improvement Commissioners have purchased, at a cost of 1,000*l.*, 13½ acres of land at Wetherby Lane, and have caused this to be laid out as irrigation ground, and the sewage of that portion of the township, estimated at 42,000 gallons daily, is utilised thereon. The cost of the outlet-works for this portion and laying out the land was 3,484*l.* The Commissioners have let the land (13½ acres) with the sewage at a yearly rent of 52*l.*, the tenant undertaking to dispose of the sewage so as not to cause a nuisance.

LEAMINGTON.

Population, including the districts of Lillington and Milverton - - - - - - -	24,700
Rateable value of the borough - - - -	£113,400
Houses - - - - - - -	4,500
Waterclosets - - - - - -	8,370
Cost of main sewers - - - - -	£16,239
Cost of outfall works, pumping station, and machinery -	£24,239
Volume of sewage every 24 hours, upwards of (gallons)	800,000
Yearly expense of pumping sewage - - -	£1,035
Yearly amount received for sewage - - - - -	£450

The royal borough of Leamington-Spa has an area of about 1,571 acres, a population of about 24,700, and 4,500 houses; the rateable value is 113,400*l.* Waterclosets are principally used, there being 8,370 in the town. The house refuse and ashes are removed from the ashpits by men and carts employed by the corporation, and about 3,000 cubic yards of this house-waste is collected annually, at a cost of 780*l.*, and given away to farmers, there being no sale for it. A system of sewerage works was commenced in 1859 and finished in 1861, but additions are made from time to time, the total cost of their works being 16,239*l.* The sewers are ventilated by 157 grids in the covers of the manholes, and 200 additional ventilators are at once to be put to the mains sewers. On completion of the sewerage works in 1861, the sewage, which formerly flowed direct into the river Leam, was intercepted by subsidence-reservoirs constructed near the bank of the river on the west side of the town. The costs of these reservoirs, tank, and outfall-works was 8,000*l.* The precipitation of the suspended matters of the sewage was accelerated by mixing with it as it arrived at the tank a certain proportion of the "milk" of lime, and violently agitating the sewage as it flowed from the tank on its way to the reservoirs of subsidence. In these reservoirs a large quantity of highly-putrescible mud was deposited and the supernatant liquid flowed into the river, carrying with it, especially in heavy rainfall, considerable portions of this mud. The annual expense of working the lime process was 500*l.*, and it failed to purify the sewage; the offensive state of the river became gradually intensified by the impure sewage of the town flowing into it, and eventually, after repeated complaints by Lord Warwick, Mr. Richard Heath, and Mr. W. Field, riparian owners, Mr. Richard Heath, on the 25th November 1864, filed a Bill of Complaint in the Court

of Chancery, and on the 1st June 1866, obtained an "interim injunction" to restrain the local board from polluting the river Leam with the sewage of Leamington. The local authority did not satisfy the Court that they were taking proper means to abate the nuisance, and an order of sequestration was, on the 2nd August 1867, issued, but suspended from time to time. Subsequently, in 1868, the local board caused the bed of the river to be cleansed, and paid the costs of this work, amounting to 1,500*l*., and also the costs of the suit, 5,000*l*. About the same time Lord Warwick caused an offer to be made to the Local Board to take from them on lease for 21 years the sewage of Leamington, and pay 450*l*. a year, provided it was delivered on to the Heathcote farms, a distance of 2 miles from the town. The local board accepted the offer on the 5th April 1870, and directed a cast-iron rising main to be laid from the works to the farm and pumping works to be erected and fitted with suitable machinery capable of pumping a volume of upwards of 800,000 gallons of sewage daily on to the farm; these works were finished and the pumping of the sewage to the "Heathcote Farm" commenced on the 5th October 1871, and the entire volume, except in heavy rainfall, has been pumped daily ever since that date. The soil of the farm is a fine loam on a sub-soil of gravel; the flood-water flows by a storm outlet into the Leam. The annual cost of pumping, including labour and materials, is 1,035*l*.

While the works were in progress the A.B.C. or Native Guano Company, on the 19th October 1868, made an offer to the local board to treat, free of cost, the sewage of the town by their process; and the local board, on the 4th March 1869, accepted their offer and permitted them to use the sheds, tanks, and outfall works for that purpose on condition that the company should remove the whole of the plant, which they proposed to erect on the site of the pumping station, when required to do so. The A.B.C. Company carried out their process until October 1871, and although it removed a large portion of the suspended impurities from the sewage, it, however, only took away therefrom a small proportion of the soluble polluting matters, and the effluent sewage was very little better than that which was obtained by allowing the raw sewage to settle in subsidence-tanks without chemical treatment.

The extraction of the "sludge" and drying it, especially in hot weather, in order to convert it into a manure, was attended with a nauseous odour and caused an intolerable nuisance, an extreme annoyance to the residents of Milverton, a populous and fashionable suburb of Leamington, who made repeated complaints to the local board of the "suffering they endured day and night from the offensive smell caused by "the method adopted by the company for drying of the sewage mud."

The Sewage Farm.

The effluent water on the date of our visit to the farm, August 18th, 1875, was sufficiently purified to be admitted into the river, as not a trace of sewage could be detected in the clear and inodorous stream which flowed from the meadows into the watercourses. By the kindness of Mr. D. Tough (bailiff to the Right Honourable the Earl of Warwick), we are enabled to give a statement showing the cropping of the farm and quantity of sewage applied thereon for the past four years. Mr. Tough also sent to us the following very satisfactory account of last year's experience.

"The farm is about 370 acres, and the whole of this area except 96 acres has been irrigated with sewage. We have also supplied sewage to

ACREAGE and CROPPING of the EARL OF WARWICK'S HEATHCOTE FARM, with QUANTITY of SEWAGE and NUMBER of DRESSINGS applied to each CROP, from 1871 to 1875.

No. of Field on Plan.	Acreage.	Description of Crop, 1871.	Description of Crop, 1872.	Quantity of Sewage applied.	No. of Dressings.	Description of Crop, 1873.	Quantity of Sewage applied.	No. of Dressings.	Description of Crop, 1874.	Quantity of Sewage applied.	No. of Dressings.	Description of Crop, 1875.	Quantity of Sewage applied.	No. of Dressings.	Remarks.
	a. r. p.			Tons.			Tons.			Tons.			Tons.		
13	12 2 16	Not in occupation	Fallow	30,109¼	4	Barley and cabbage	35,737¼	7	8a. 2r. 0p. I. R. grass	102,493½	31	8a. 2r. 0p. I. R. grass	58,317½	18	Light loam and gravel subsoil.
,,	,,	-	-	—	—	8a. 2r. 0p. I. R. grass sown in spring with corn.	23,497	5	4a. 0r. 16p. cabbage	11,054½	6	4a. 0r. 16p. fallow for cabbage	2,905¾	2	—
,,	,,	-	-	—	—	-	—	—	-	—	—	,, cabbage	29,280	15	—
20, 21, 22	14 0 31	Wheat and potatoes	Cabbage, parsnips, onions, and carrots.	75,340	10	Wheat barley	—	—	8a. 0r. 0p. spring cabbage	33,098¾	9	I. R. grass	158,265¾	27	Ditto.
,,	,,	-	-	—	—	8a. 0r. 0p. spring cabbage planted after corn crop.	2,474½	1	6a. 0r. 31p. I. R. grass	54,260¾	20	6a. 0r. 31p. fallow for mangold after grass.	23,056½	8	—
,,	,,	-	-	—	—	-	—	—	Turnips after cabbage	5,584¾	2	—	—	—	—
23, 29	15 2 16	Potatoes and oats	Wheat	—	—	Potatoes and mangold	—	—	Wheat	—	—	Beans	—	—	Clay, farmyard manured.
24	5 1 12	Wheat	Potatoes	—	—	3a. 0r. 0p. cabbage	8,857	5	Fallow for barley	3,965¼	2	I. R. grass	146,675¾	49	Light loam, and gravel subsoil.
,,	,,	-	-	—	—	2a. 1r. 12p. peas	—	—	Grass sown at Michaelmas	18,894½	8	—	—	—	—
25	10 1 17	Barley	I. R. grass	104,883½	26	I. R. grass	152,317¼	29	9a. 1r. 17p. I. R. grass	113,432¼	29	9a. 1r. 17p. cabbage	32,703¼	8	Light loam, and gravel subsoil.
,,	,,	-	-	—	—	-	—	—	1a. 0r. 0p. cabbage plants	4,820½	12	1a. 0r. 0p. plants	2,410¼	6	—
,,	,,	-	-	—	—	-	—	—	10a. 1r. 17p. cabbage after grass	12,294¼	3	—	—	—	—
26, 30, 52, 68	22 3 37	Permanent pasture	Permanent pasture	—	—	Permanent pasture	—	—	Permanent pasture	—	—	Permanent pasture	—	—	Clay.—farmyard manured.
27, 28	13 3 3	Peas	I. R. grass	122,832½	18	I. R. grass, 4 cuttings	126,518	19	13a. 3r. 2p. savoys	15,642½	3	I. R. grass	279,010	42	Light loam, gravel, and clay subsoil.
,,	,,	-	-	—	—	Savoys after grass	93,830¼	15	7a. 0r. 0p. cabbage, 1st cut	37,407	12	—	—	—	—
,,	,,	-	-	—	—	-	—	—	,, ,, 2nd ,,	38,289	13	—	—	—	—
,,	,,	-	-	—	—	-	—	—	6a. 2r. 3p. wheat	—	—	—	—	—	—
,,	,,	-	-	—	—	-	—	—	Grass after cabbage and wheat, sown at Michaelmas.	24,895¼	4	—	—	—	—
41, 45, 46, 67	26 0 34	Permanent pasture	Permanent pasture	53,692¾	5	Permanent pasture	9,735¾	1	Permanent pasture	37,174	4	Permanent pasture	66,635	7	Clay, and marl.
42	8 3 0	Mangold	Wheat	—	—	I. R. grass	52,382¼	17	I. R. grass	67,297¼	20	Mangold, swedes, and carrots	—	—	Clay, and gravel.
43	9 0 4	Swedes	Barley	—	—	-	—	—	I. R. grass	121,483¼	29	Mangold and 5 acres belonging of ditto belonging to No. 42.	117,463¾	18	Light loam and gravel subsoil.
,,	,,	-	Grass sown at Michaelmas	16,152¼	4	I. R. grass	126,603½	31	Fallow for roots after grass	6,307	2	—	—	—	—
,,	,,	-	-	—	—	-	—	—	-	—	—	Fallow for roots (No. 43)	18,050¾	5	—
44	6 3 17	Mangold	Wheat } Clover sown with corn.	Wheat, 22,120¼	7	Clover }	51,138½	7	Beans	—	—	Wheat (grass grown at Michaelmas).	994	—	Ditto.
47	10 0 32	Barley	Oats }	45,095½	7	Clover }			Wheat (grass at Michaelmas)	17,937	4	I. R. grass	166,470	36	Ditto.
48	11 0 36	Swedes	Wheat	—	—	I. R. grass	161,136	31	I. R. grass	103,084¾	23	Beans	—	—	Ditto.
,,	,,	-	Grass sown at Michaelmas	20,886½	4	—	—	—	—	—	—	—	—	—	—
49, 55, 56	23 2 8	Wheat	Beans	—	—	Wheat	—	—	Oats	—	—	19a. 2r. 8p. swedes and turnips	—	—	Heavy clay.
,,	,,	-	-	—	—	-	—	—	-	—	—	4a. 0r. 0p. mangold	7,352	4	Farmyard manured.
50	10 3 24	Permanent pasture	Permanent pasture	6,962¾	2	Permanent pasture	—	—	Permanent pasture	—	—	Permanent pasture	—	—	Farmyard manured, clay and marl.
51, 53	18 1 4	Wheat	Mangold	66,381¼	10	Wheat	—	—	Beans	—	—	Wheat	—	—	Heavy loam, clay and marl subsoil.
54	9 1 29	Wheat	Beans, 4 acres sewaged	1,932½	1	Wheat	—	—	I. R. grass	119,094¾	29	I. R. grass	98,734¾	25	farmyard manured.
,,	,,	-	-	—	—	Grass sown with corn	30,407½	8	-	—	—	-	—	—	Light loam, clay subsoil.
57	20 2 33	Pasture	Wheat	—	—	Beans	—	—	Wheat	—	—	Oats	—	—	Heavy clay, farmyard manured.
58, 59	20 0 15	Peas, swedes, and turnips	Wheat	18,216¼	2	Mangold and swedes	28,779¼	4	Wheat	—	—	Beans	—	—	Heavy loam, clay subsoil.
,,	,,	-	-	—	—	-	—	—	Fallow for beans	13,777½	2	-	—	—	Farmyard manured.
60	10 1 7	Barley	Swedes	—	—	Wheat	—	—	Beans	—	—	Wheat	—	—	Ditto.
61	12 1 3	Barley	Swedes	—	—	Wheat	—	—	Clover	—	—	Clover	—	—	Ditto.
62	5 1 30	Wheat	Clover	—	—	Wheat	—	—	Barley	—	—	Potatoes	—	—	Light loam, farmyard manured
63	14 0 36	Permanent pasture	Permanent pasture, 4 acres sewaged	2,276½	1	Permanent pasture, 4 acres sewaged	12,489	8	Permanent pasture	—	—	Permanent pasture	—	—	Ditto.
64	10 1 34	I. R. grass	I. R. grass	92,439½	18	Wheat	—	—	4 acres fallow for carrots and parsnips.	17,806¾	10	7a. 0r. 0p. cabbage	11,350	4	Light loam, and clay subsoil.
,,	,,	-	-	—	—	-	—	—	4 acres fallow for carrots and parsnips.	4,861	3	2a. 1r. 34p. mangold	4,559¾	4	—
,,	,,	-	-	—	—	-	—	—	6a. 1r. 34p. potatoes	—	—	1a. 0r. 0p. rhubarb strawberries	—	—	—
65	10 3 11	I. R. grass	I. R. grass	111,384	21	Wheat	—	—	Mangold	63,529	15	Wheat	—	—	Ditto.
,,	,,	-	-	—	—	Fallow for mangold	27,886½	6	-	—	—	Fallow for mangold	9,176½	2	—
66	10 2 25	Barley	Clover	29,520¾	7	Wheat	—	—	Mangold	—	—	Oats	—	—	Clay, farmyard manured.
69	9 2 3	Not in occupation	Beans	—	—	6a. 0r. 0p. mangold	3,455½	2	Wheat	—	—	Barley	—	—	Ditto.
,,	,,	-	-	—	—	3a. 2r. 3p. fallow	—	—	—	—	—	—	—	—	—
71	7 2 36	Not in occupation	Swedes	3,093¼	1	Wheat	—	—	Turnips	—	—	Barley	—	—	Light loam, clay-subsoil, farmyard manured.
72	9 1 36	Do.	Wheat	—	—	Swedes	—	—	-	—	—	Clover	13,886¼	4	—
,,	,,	-	Sewage supplied to farmers	104,641¾	—	Sewage supplied to farmers	344,196¾	—	Sewage supplied to farmers	270,133½	—	Sewage supplied to farmers	205,628¾	—	—
	370 3 29	Acreage of farm.	Total for 1872	927,961		Total for 1873	1,291,441¾	—	Total for 1874	1,318,618½		Total for 1875	1,452,927		

the adjoining farmers on about 80 acres of land for which we received from 20*s.* to 30*s.* per acre. The sewage of Leamington is pumped to the farm daily, and is used in winter on fallow or grass-land, and in summer on grass, cabbage, carrots, parsnips, onions, mangolds and turnips. We never apply any sewage to the root crops, with the exception of cabbage, until May or June; but this latter crop is sewaged in the spring as soon as the weather will permit. We have tried sewage on corn crop, but found it difficult to apply it while the crop is growing, in fact sewage ought not to be applied to corn crops. The last season we had excellent crops of everything grown on the farm. The farm is worked with 13 horses which are all fed on the sewage produce and do remarkably well."

"We have also a dairy of 40 cows, the milk is sold on the farm at 11*d.* per gallon the cows are all stall fed in summer on grass, and in winter on turnips, mangolds, and hay and straw, cut into chaff, and a little artificial food. The calves are reared and sold when two or three years old; we also keep a few sheep on the farm. During the last two years we have gained 10 silver cups and a great many money prizes for roots grown by sewage."

MERTHYR TYDFIL.

Population (about) - - - - - - -	55,000
Rateable value - - - - - - -	£135,000
Houses - - - - - - - -	10,778
Waterclosets - - - - - - -	8,000
Cost of outlet sewer, purchase and laying out of land as filters, and as sewage farms - - - - -	£53,330
Yearly rent of 59 acres of land held on lease - -	£298
Volume of sewage every 24 hours, about - (gallons) -	1,200,000

Privies (2,800) are cleansed at the expense of the occupiers of the houses to which they belong.

Merthyr Tydfil.—This urban sanitary district has an area of 17,714 acres, a population of about 55,000, and a rateable value of 135,000*l.* There are 10,200 inhabited and 578 uninhabited houses; connected with these are about 8,000 waterclosets and the drainage from about 2,800 privies. In 1864, the waterworks were completed, and it then became necessary to provide for the disposal of the used water which greatly augmented the volume of the sewage. Plans were prepared by Mr. S. Harpur, the engineer, to the local authority for the disposal of the sewage, and approved; the works were commenced in November 1865, but owing to the failure of the contractor, were not completed till 1868, at a cost of 28,000*l.*; the crude-sewage was then discharged into the Taff. Soon after the works were completed a Bill of Complaint was filed in the Court of Chancery by Messrs. Nixon and Company, colliery proprietors, Ynysowen, to restrain the local authority from polluting the Taff, and an interim injunction, afterwards made perpetual, was granted. In April 1869, the engineer to the local authority submitted a comprehensive scheme for disposal of the sewage by irrigation; this was sanctioned, it embraced the taking and laying out at Troedyrhiew, within the parish of Merthyr, 75 acres of land; also 60 acres of common land, and 240 acres of enclosed land in the parishes of Llanfabon and Llanwonno, at

from 8 to 11 miles from Merthyr, all in the basin of the Taff; these farms have a fine loamy soil with a gravelly soil. The outfall-works, consisting of 19,000 lineal yards of brick, timber, iron, and earthenware-conduit (from 12 to 24 inches in diameter) were completed in 1873. While these works were in progress the Master of the Rolls directed that means should be adopted for mitigating the nuisance in the Taff, by separating the coarser solid particles of sewage and prevent them flowing into the river; the local authority then ordered filter-tanks to be constructed near the outfall, and caused the sewage to be filtered through a medium of furnace ashes 3 feet deep, a small quantity of cream of lime being added to the sewage before filtration; this method not having satisfied his lordship he issued an order of sequestration, and from that order the local authority appealed. The Lords Justices of Appeal in July 1870 directed Mr. J. Bailey Denton, C.E., to examine and report on the best means of preventing the nuisance complained of, and he recommended that 20 acres of the 75 acres of land at Troedyrhiew should be laid out as land filters, and used on the intermittent principle proposed by the Rivers Pollution Commission; these works were subsequently carried out under his superintendence, and worked up to early in the year 1872. The addition of lime to the sewage was then discontinued, and the land-filter-beds have since been treated as ordinary irrigation ground, and are now so used, together with 230 acres of the other portions of the land, as a sewage irrigation farm. The average dry weather flow of the sewage is 1,200,000 gallons. There are fine storm outlets into the Taff. The cost of the several works was as follows:—Outfall-sewer from Troedyrhiew to the Ynyscadudug Farm, 16,002*l.* 2*s.* 10*d.*; building subsidence tanks, 387*l.* 15*s.* 1*d.*; laying out land-filtering areas (including drainage and the carriers upon 20 acres), 4,606*l.* 12*s.* 4*d.*; forming, draining, and making carriers on the remaining 55 acres at Troedyrhiew, 1,408*l.* 6*s.* 5*d.*; purchase and laying out, draining, and fencing the common land at Navigation Farm, 4365*l.* 11*s.* 5*d.*; purchase, laying out, and draining land at Ynyscadudug Farm, 14,387*l.* 6*s.* 0*d.*; purchase of Tyrybont estate, 30 acres, at Troedyrhiew, 3,002*l.* 2*s.* 6*d.*; purchase of Park Newydd estate of 67 acres, 9,170*l.* Total, 53,329*l.* 16*s.* 7*d.*

The sewage flows by gravitation on to the farms, and the annual cost of cropping the land and applying the sewage is 2,391*l.* 5*s.* 10*d.*; to this must be added the yearly rent paid by the local authority for that portion of the land held on lease (viz.) 298*l.* The accounts of the year have not been made up, but it is feared that the receipts will not cover the expenditure. The Troedyrhiew Farm of 70 acres, of which there are about 2 acres of roads, has this year produced the following crops: Italian rye grass, 34½ acres; permanent grass, 5 acres; cabbage, 8 acres; mangolds, 6 acres; swedes, 5 acres; red wheat, 3 acres; beans, 4 acres; rhubarb, ½ acre; seed beds, 2 acres. The Navigation Farm (60 acres of common land, of which roads occupy one acre) produced Italian rye-grass, 15 acres; white oats, 35 acres; willows, 3 acres; mangolds, 1 acre; and swedes, 1 acre. Ynyscadudug Farm (93 acres only bore crops) produced hay from 83 acres of permanent grass; Italian rye grass, 4 acres; white oats, 4 acres; and swedes, 1 acre. There were very good crops of hay on the land at Ynyscadudug which realized 6*l.* per acre (the land before the sewage was applied was let at 15*s.* per acre). The Italian rye grass realised 7*l.* per acre on common land which was formerly worth 2*s.* 6*d.* per acre. The oats were sown late and only yielded a light crop. The wheat produced 25 bushels to the acre and a large quantity of fine straw. The mangolds and swedes produced each

30 tons to the acre. The Italian rye grass at Troedyrhiew was cut six times and gave an average of 6 tons per acre at each cutting, and fetched 1*l*. per ton on the farm; the pickling cabbage sold for 50*l*. per acre, and the other cabbage for 30*l*. per acre.

In addition to the sewage 30 tons of stable dung was used on the Troedyrhiew Farm, which is situate within 250 yards of the village. No complaints have been made of nuisance arising from the farm, or of the condition of the effluent water flowing into the river, as it has invariably been bright and pure. The tanks are cleaned out every fortnight, and the "sludge" is mixed with the house refuse and dug or ploughed into the land.

The inhabitants living near portions of the sewage-farms speak of them as the "gardens."

RUGBY.

Population (about) - - - - -	8,400
Rateable value - - - - - -	£45,000
Houses - - - - - - -	1,700
Waterclosets - - - - - -	1,400
Cost of outlet works and laying out farm - - -	£5,800

This Local Board of Health district has an area of 1,617 acres, and a rateable value of 45,000*l*. The sewage of 8,400 inhabitants of Rugby, living in 1,700 houses, is disposed of in irrigation. There are 1,400 waterclosets, very few privies, and no cesspools. A system of sewerage has been carried out at a cost of 5,764*l*.; the works were commenced in 1852, and the main-outfall was into the river Avon. On completion of the works the late Mr. Walker applied to the local board to be allowed to divert the sewage from the river, and to use it on his own adjoining land, and concession having been granted to him, a reservoir was constructed, and the sewage was pumped therefrom through cast-iron pipes, laid over the entire farm, on which were fixed a number of hydrants, in suitable situations, and the sewage was distributed from thence, as required, by a flexible hose and jet.* The outlet into the Avon was then only used for storm-water, or when the application of the sewage to the land was from any cause interrupted. This mode of irrigation was carried on for some time; but as Mr. Walker did not deal with the whole of the sewage, the river became polluted, and an action at law was, in August 1855, commenced against the local authority by Mr. Charles Caldecott, of Holbrook Grange, a riparian proprietor, but a technical objection having been taken, the action was abandoned. The local board then discussed the best means of disposing of the sewage, and decided in 1857 to hire from Mr. Walker 65 acres of land, at the yearly rent of 290*l*., including rates and taxes, to construct subsiding tanks, and to cause the farm to be laid out on the surface irrigation principle, at a cost of 5,800*l*. A volume of 400,000 gallons of sewage every 24 hours (150,000 gallons being subsoil water,) has

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* The cast-iron pipes were extended over an area much larger than could be supplied with sewage, and the cost of pumping and of irrigation by hose and jet proved to be too expensive and was consequently abandoned.

flowed continuously since that date over the land. No complaints have been made of the state of the effluent from the farm into the river. The local board at Lady-day, 1874, sublet the land hired of Mr. Walker, to Mr. J. A. Campbell, at a yearly rent of 350*l.*, the local board maintaining their right to dispose of the sewage upon the land, and paying the labour cost of the distribution. In 1871, in order to utilize the sewage of another portion of the district, the local authority hired of the rector of Rugby, about 13 acres of land, at the yearly rent of 54*l.*, and caused the sewer to be extended, and the sewage to flow on to this land; they have since sublet it, with the sewage, for 79*l.* per annum.

Mr. J. A. Campbell has kindly given to us the following information:—

Acreage of Sewage Farm under Crop, 57*a.* 0*r.* 19*p.*

Crops, 1874.

	a.	r.	p.
Wheat - - - - -	21	3	22
Beans - - - - -	4	2	29
Oats - - - - -	8	2	2
Italian rye grass - - -	22	0	11
Total -	57	0	24
Cash produce of farm - - -	701	11	1½
Expenses, including rent (360*l.*) -	725	13	10
Balance against farm -	£24	2	8½

NOTE.—See pages 86, 87, as to raw and effluent sewage.

TUNBRIDGE WELLS.

Population (about) - - - - - -		23,000
Rateable value - - - - - - -		£142,914
Houses - - - - - - - -		5,750
Waterclosets - - - - - - -		5,635
Cost of outlet works, purchases, and laying out of farms -		£87,243
Volume of sewage every 24 hours - -	(gallons)	650,000

Tunbridge Wells, an urban sanitary district in the counties of Sussex and Kent, disposes of the sewage of its 23,000 resident inhabitants by irrigation. The district has an area of 3,352 acres, and a rateable value of 142,914*l.* 10*s.*; the town portion is drained by main sewers of irregular form constructed of brick, the branch sewers are of stoneware pipes. Waterclosets are chiefly used, the number being 5,635 in the town. The sewage was formerly allowed to run direct into the Calverley Brook.

On the 24th November 1865, an injunction was obtained by Mr. Frederick David Goldsmid of Summer Hill Park to restrain the Improvement Commissioners from polluting the "brook," and the latter having failed to satisfy the court that they had rendered the sewage inoffensive, an order of sequestration was subsequently granted; this order, however, was suspended from time to time, and finally discharged

on 2nd July 1874, on the Commissioners undertaking to intercept the sewage, and practically purify it before it flowed into the brook; to defray the expense of cleaning out the Summer Hill Lake which amounted to 744*l.* 17*s.* 8*d.*; and also to pay the costs of the suit, about 3,000*l.*

To satisfy these conditions, the Improvement Commissioners caused intercepting sewers and outfall works to be constructed, and they also purchased two farms, one of 120 acres of stiff loamy soil 1½ mile to the north, and the other of 165 acres of light open soil 3½ miles to the south of the town. These farms are prepared and laid out for irrigation, and the sewage, which is not treated by any chemical process, flows by gravitation through subsidence-tanks, and a daily volume of about 414,000 gallons is thus delivered on to an area of 118 acres at the South Farm, and about 236,000 gallons on to an area of 100 acres at the North Farm, the solid refuse is removed from the tanks when necessary and sold to farmers, who clean out the tanks, remove the deposited material, and pay 65*l.* a year for it. The effluent water from the North Farm flows into the Calverley Brook, and that from the South Farm into the Brodwater Brook, and the County Ditch, which are tributaries of the Medway. Samples of this water are collected every fortnight by the farm bailiffs, and summitted to the Sewage Outfalls Committee. No complaint has been made of the state of the effluent water since the removal of the order of sequestration. The crops produced this year were, on the

NORTH FARM.

Italian Rye Grass, 30 acres.	Pasture and Meadow, 20 acres.	Wheat, 15 acres.	Oats, 10 acres.	Beans, 9 acres.	Barley, 3 acres.	Winter Oats, 5 acres.	Mangolds, 3½ acres.	Swede Turnips, 3 acres.	Carrots and Cabbage, 1½ acres.
Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —
65 tons in five cuttings.	A heavy crop of coarse hay stacked on the farm.	5 qrs.	9 qrs.	4 qrs.	5 qrs.	9 qrs.	50 tons	25 tons	—

SOUTH FARM.

Italian Rye Grass. 21 acres.	Pasture and Meadow, 30 acres.	Hops, 22 acres.	Wheat, 17 acres.	Oats, 14 acres.	Beans, 4 acres.	Mangolds, 3 acres.	Swede Turnips, 5 acres.	Clover, 2 acres.
Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —	Per acre. —
40 tons	Cut for hay or pastured.	13 cwt.	4½ tons	6 qrs.	3 qrs.	40 tons.	30 tons.	—

The cost of the sewage works (purchase of and laying out of farms, law costs and arbitration, expenses relating to purchase of farms, and compensation to tenants) has been 87,243*l.*

Northern Sewage Farm.

Profit and Loss Account for the Year ending the 25th of March 1876.

Receipts. Dr.

	£	s.	d.	£	s.	d.
To sale of 11 cattle (8 steers 2 cows, and a calf - - -	213	4	6			
,, sale of 40 sheep -	113	10	0			
,, do. 2 horses -	26	0	0	352	14	6
,, do. rye grass -	462	3	9			
,, sale of wheat, oats, ,, barley, peas, and beans	314	17	6			
,, sale of mangolds -	102	0	5			
,, do. milk - -	4	8	6			
,, do. manure -	88	6	6			
,, do. straw - -	15	15	5			
,, do. fagots - -	1	12	6			
,, cattle and pony keep	9	6	6			
,, garden, meadow, and cottage rents -	87	12	0	1,086	3	1
,, outstanding accounts				20	10	2
Austen's Valuation made to 25th March, 1876.						
To 4 horses - -	205	0	0			
,, 33 store beasts -	453	0	0			
,, manures - -	87	10	0			
,, hay, straw, and roots	96	5	0			
,, corn - - -	231	15	0			
,, cultivations and young seeds - -	119	9	0			
,, implements of husbandry - - -	254	2	6			
,, man applying sewage	29	18	0	1,476	19	6
				£2,936	7	3

Expenditure. Cr.

	£	s.	d.	£	s.	d.
By valuation on the 25th March, 1875, brought forward - -				1,251	13	0
,, purchase of 14 cattle (7 steers, 1 bull, and 6 calves) - -	80	9	0			
,, purchase of 40 sheep	84	0	0			
,, do. 2 horses	132	6	0	296	15	0
,, farm implements and smiths' works - -	20	17	11			
,, seeds - - -	73	18	9			
,, provender - -	59	1	7			
,, bailiff's wages -	97	9	8			
,, farm labourer -	489	11	1			
,, repairs to roads -	4	19	2			
,, do. farm buildings - - -	7	17	0			
,, rates and taxes -	44	18	2			
,, insurance - -	9	11	9			
,, miscellaneous - -	54	16	6	863	1	7
By outstanding accounts				52	18	2
,, balance - -				471	19	0
				£2,936	7	3

Southern Sewage Farm.

Profit and Loss Account for the Year ending the 25th of March 1876.

Receipts. Dr.

	£	s.	d.	£	s.	d.
To sale of 67 cattle (44 steers, 12 heifers, and 11 calves) - -	1,110	5	3			
,, sale of 63 sheep -	160	15	10	1,271	1	1
,, do. rye grass -	155	18	6			
,, do. wheat and oats	204	3	0			
,, do. mangolds, &c.	61	18	0			
,, do. manure -	30	0	0			
,, do. straw - -	2	6	0			
,, do. hops (less commission, &c.) -	1,363	5	2			
,, sale of hop-pole fagots	3	0	0			
,, do. cottage rents -	49	9	0	1,869	19	8
,, outstanding accounts	83	3	7			
,, do. stock, 12 sheep sold to E. Carey	31	4	0	114	7	7
Austen's Valuation made to 25th March, 1876.						
To 7 horses -	279	0	0			
,, 27 store beasts	534	0	0			
,, 12 sheep	32	8	0			
,, manures -	71	8	0			
,, hay and straw -	32	10	0			
,, corn - - -	176	15	0			
,, cultivations and young seeds - -	112	10	0			
,, hop-poles, manure, and labour - -	505	0	0			
,, implements of husbandry - - -	234	2	6			
,, man applying sewage	29	18	0	2,007	11	6
				£5,262	19	10

Expenditure. Cr.

	£	s.	d.	£	s.	d.
By valuation on the 25th March, 1875, brought forward - -				2,370	0	9
,, purchase of 65 cattle (47 steers, 11 cows, and 7 calves) - -	727	11	0			
,, purchase of 76 sheep	154	13	0			
,, do. 1 horse	55	0	0	937	4	0
,, farm implements and smiths' work - -	41	13	7			
,, seeds - - -	64	2	7			
,, provender - -	132	16	1			
,, hop-poles - -	146	13	0			
,, hop sets - -	1	7	0			
,, artificial manures -	41	3	0			
,, bailiff's wages -	134	6	8			
,, farm labourer -	424	18	4			
,, labour on hops -	450	8	6			
,, rates and taxes -	112	10	4			
,, insurance - -	8	1	6			
,, repairs to farm buildings - - -	33	1	0			
,, hop pocketing -	56	14	5			
,, coal and lime -	13	4	6			
,, miscellaneous -	61	17	11	1,722	18	5
,, outstanding accounts				176	9	0
,, balance - -				56	7	8
				£5,262	19	10

WARWICK.

Area (acres) - - .. - - -	
Population (about) - - - - -	11,000
Rateable value - - - - - -	£43,339
Houses - - - - - - -	2,400
Waterclosets - - - - - -	2,000
Cost of main sewers - - - - -	£6,400
Cost of outlet works, pumping station, and laying out farm -	£10,085
Volume of sewage every 24 hours - - (gallons)	700,000

This borough has a rateable value of 43,339*l.*, and a population of about 11,000 residing in 2,400 houses to which are attached 2,000 waterclosets; there are very few privies. Sewerage works were commenced in 1856 and finished in 1857, at a cost of 6,400*l.*, and the sewage then flowed by two main outfalls into the Avon. The river soon became badly polluted and the riparian proprietors, Miss Ryland, Mr. Edward Greenway, M.P., and Mr. John Staunton, complained of the nuisance and threatened proceedings to compel the corporation to abate it. The outfall sewers were, in 1869, extended to a farm on the Stratford Road about 1¼ miles from the town. This farm of 135 acres, of stiff clay land, was taken on lease for 21 years at a yearly rent, for the first five years, of 404*l.*, and for the remainder 16 years of the term at 471*l.* 10*s.* The corporation directed the farm to be laid out to receive the sewage, and a volume estimated at 700,000 gallons (one third being subsoil water) has been pumped every 24 hours to a height of 64 feet and distributed in irrigation over the land. The old sewers have been made available as conduits for surface water with outlets direct into the river. The sewers are being ventilated by pipes with swan-neck tops carried up near to the surface of the streets into small detritus pits covered over with iron grids. The outlet sewage works, including engines, pumps, and pumping-main and laying out the farm cost 10,084*l.* 18*s.* 1*d.* The working expenses are 572*l.* 11*s.* 6*d.* per annum. From 1869 to September 1875 the corporation worked the farm, but have since leased it to a limited company for 21 years at the annual rent of 471*l.* 10*s.*, and have assigned as reasons for so doing that there is an annual loss on the farm, that the corporation have had no capital to properly carry it on, and that the working expenses are taken out of the general district rate.

During the 12 months ended September 1875, the farm has been cropped with oats, 5 statute acres, swedes 6 acres, mangolds 15 acres, beans 3 acres, celery, cabbage and potatoes 4 acres, Italian rye grass 39 acres, and permanent grass 49 acres; besides these crops there was in fallow and roads an area of about 14 acres. The oats produced a very fair crop; the swedes were good and gave about 20 tons to the acre. The mangolds were a fair average crop of about 40 tons to the acre. Some of the Italian rye grass was excellent, especially that grown on the land which had been drained, this being cut six times. There was also a very good crop of hay got off the permanent pasture; the company propose to stock the farm and to under-drain the whole of it; the drains will be 12 feet apart, and at depths varying from 3 feet 6 inches to four feet; they also propose to erect suitable farm buildings.

The expenditure on the sewage-farm for 1873, including rent, labour, &c. was 1,369*l.* 6*s.*, and the receipts from the sale of the produce was 907*l.* 6*s.* 10½*d*; whilst in 1874 the expenditure was 1,494*l.* 18*s.* 8*d.*, and the receipts were 1,071*l.* 10*s.* 4*d.*

Note.—See page 89 as to raw and effluent sewage.

WEST DERBY.

Public Offices, Stoneycroft, near Liverpool.
24th April 1876.

We now furnish the information asked for in letter of the 31st ultimo as to this Board's sewage farm, &c.

For the sake of convenience we have set out the inquiries below, and against them have placed the answers seriatim :—

Area in acres of land used and to be used for the utilization and purification of the sewage of the district.	207 statute acres. A plan is sent herewith.
1. If purchased, the cost ?	The *nett* amount paid owners for the land has been 30,325*l.* 2*s.* 0*d.* The total amount paid for tenants' compensation and for the costs of the owners and tenants is 3,916*l.* 1*s.* 9*d.*, or about 166*l.* per acre.
2. If leased, the terms and rental ?	
3. The cost of preparing the land ?	The *nett* amount paid for "laying out" the land only has been 8,934*l.* 9*s.* 8*d.*, which includes wages, piece work, drain tiles and pipes; carting tiles and rock for roads; timber, lime, cement, cinders, horse keep, and such like, or about 43*l.* per acre.
4. The estimated annual working costs ?	For the year ending 25th March 1875 (the last year for which the accounts have been audited), the cost of cropping, cultivating, and applying sewage was 2,334*l.* 15*s.* 3*d.* This amount does *not* include the instalments of the loan and the interest.
5. The daily volume of sewage in gallons to be applied ?	At 30 gallons per head per day. Population into eastern and western sewers, 24,100 = 723,000 gallons per day. Remainder of population, 7,300, goes into corporation sewers.
6. The local population ? -	The population, whose sewage is already applied to the farm, is 18,600 persons; the sewage of 5,500 more persons will shortly be diverted into the tanks which are now being constructed at the farm, and are almost completed, and will thence be pumped on to the farm land. The sewage of the remainder of the population of the district, viz., 7,300 persons, passes into the sewers of the corporation of Liverpool.
7. The number of waterclosets in use ?	3,000 in western area, and 220 in eastern area. This is exclusive of waterclosets draining into corporation sewers.
8. The number of privies and ashpits ?	In western area about 1,042 middens, and in eastern area about 591 middens. In the majority of cases there are two privies to each midden. This is exclusive of those in corporation area.

9. The annual cost of cleansing these?	700*l.* a year. The work is done by a contractor. This includes those in corporation area.
10. The weight in tons of the refuse?	The probable weight from middens and dry ashpits to be removed per annum is abont 17,000 tons in the whole of the district.
11. The price per ton obtained if sold?	The refuse is the property of the contractor.
12. The total cost of the works and land and preparation of this land for use as a sewage farm is required?	To 24th March 1876, 61,873*l.* 5*s.* 9*d.*, which includes the items referred to in answers to the first and third queries; the surveying, engineering, and legal expenses, and all other costs and expenses. The amount estimated still to be expended to wholly complete the works at the farm is 1,476*l.* 14*s.* 3*d.*, making the total cost 63,350*l.* 0*s.* 0*d.*
13. The annual cost of working the Sewage Farm?	See answer to query No. 4 above.
14. The estimated income to be obtained from the Sewage Farm?	The total income of every description for the year ending 25th March 1875 (the last year for which the accounts have been audited) was 3,349*l.* 10*s.* 10*d.*
15. Is the land yet in use as a sewage farm, and, if so, what crops have been grown, and what did they sell for?	Yes, and all but 30 acres has had sewage applied to it. In the year ending 25th March 1875, the crops and the amounts they realized, being the produce of the farm, were as follows:—

	£	s.	d.
Rye grass - - -	1,135	17	4
Vetches - - -	26	10	8
Mangel wurzel - - -	228	16	2
Turnips - - -	106	17	8
Carrots - - -	121	9	7
Peas - - - -	334	4	5
Barley - - - -	55	17	0
Oats - - - -	63	0	3
Cabbages and savoys - -	109	15	7
*Potatoes - - -	351	15	7
*Willows - - -	12	10	8
Total	£2,546	14	11

* The land on which the potatoes and part of the willows were grown has had no sewage applied to it.

(Signed) Radcliffe and Layton,
Clerks to the Board.

Note.—This farm had not been brought fully into operation when this return was made.

APPENDIX No. II.
FILTRATION.

KENDAL.

Area (acres) - - - - - -	410
Population, about - - - - - -	13,700
Annual rateable value - - - - -	£44,600
Houses - - - - - - -	2,727
Waterclosets - - - - - -	450
Sewerage works, cost - - - - -	£18,000
Sewage farm, cost - - - - - -	£16,371
Repairs to buildings, cost - - - - -	£700
Laying out of filter beds on farm (cost) - - -	£1,400
Cost, yearly, of disposing of sewage - - -	£110
Receipts for corps and grazing - - - -	£495
Volume of sewage every 24 hours (gallons) - -	750,000

Kendal, an ancient market town and modern borough of about 13,700 inhabitants in Westmoreland, 262 miles north-west by north from London, is situate on the banks of the river Kent, and on the borders of the Lake district; it has a moist climate, the local rainfall being about the heaviest throughout the year of any town in England, ranging from 60 to 80 inches. Woollen cloth has been manufactured from the time of the reign of Edward III. There are at present large woollen manufactories, common Brussels and Kidderminster carpets, large tannaries, paper mills, and marble works. The waste and polluted water from these several works is now diverted from the river by the new intercepting sewers.

This borough has adopted the process suggested by the Rivers Pollution Commission (*i.e.*) "*downward intermittent land filtration*," combined with irrigation, adapted to cleanse the filthy sewage produced by 13,700 inhabitants and the liquids polluted by manufacturers. The borough has an area of 410 acres and a rateable value of 44,600*l.* A system of sewerage was carried out between the years 1868 and 1872 at a cost of 18,000*l.* Connected with this system there are 2,727 houses, 450 waterclosets, and the overflow from about 1,600 common privies. The sewage flows by gravitation to the "Wattsfield Estate," an area of 66 statute acres, which the local authority purchased for 16,371*l.*, about 248*l.* per acre. Subsidence-tanks were built at the outfall of the main-sewer into which sewage is discharged, and from thence flows over 16 acres of the land which had been levelled at a cost of 400*l.*, or 25*l.* per acre. The area so prepared has, however, been found to be insufficient to purify the sewage, the effluent flowing from the land into the river having caused a nuisance, which was complained of by Captain Braithwaite Wilson and other riparian owners. The local authority then called in Mr. J. Bailey Denton, who advised that the whole of the 16 acres should be laid out as land-filter-beds at a cost of 1,000*l.*, or upwards of 60*l.* per acre. The Board did not, however, consider that the work could be done for that sum, and directed that 5 acres only be so laid out, and this area has cost 1,400*l.*, or 280*l.* per acre. A volume of sewage every 24 hours of about 750,000 gallons (of which about 350,000 gallons is subsoil water from springs tapped during the execution of the sewerage works) has flowed continuously on to the 5 acres of land-filter-beds, and occasionally, as required, on to the remaining 11 acres of land. This small area clarifies the sewage so as not to be a nuisance; but in practise it is found too limited for crops to be successfully grown upon it, and, therefore, the corporation have caused an additional area of 5 acres to be prepared, for the reception of the sewage, and it is believed that upon the 10 acres of filter-beds not only will the foul waste of the

inhabitants and refuse from manufactures and dye works be properly cleansed, but that sufficient crops will be grown upon the land-filter-beds to pay the annual expenses of thus utilizing the sewage. During the year 1875, there has been grown on the present land-filter-beds (5 acres) cabbage, mangolds, carrots, celery, and rhubarb, which sold for 100*l*., on the other 5 acres oats, vetches, and Italian rye-grass, which realised 75*l*., and on the remaining 6 acres a good crop of hay which sold for 45*l*., and this plot has been fed off since the hay was got. The yearly costs of applying the sewage to the 16 acres is 110*l*., including 35*l*., the cost of cleaning the subsidence-tanks. The remaining portion of the farm, to which the sewage is not applied, has farm buildings upon it and the corporation spent last year in the repairs to these buildings 700*l*.; this land is let out as grazing ground and produces 275*l*. yearly.

The soil of the farm is a very fine sandy loam upon a subsoil of gravel, and the effluent water filtering through this into the river is bright and clear. The cleansing of privies is not done by the local board, but by and at the cost of the occupier, and the refuse is sold to farmers.

APPENDIX No. III.

PRECIPITATION, CHEMICAL, AND MECHANICAL PROCESSES.

BIRMINGHAM.

Area	(acres)	8,420
Population about		350,000
Rateable value		£1,229,844
Inhabited houses		83,420
Waterclosets, about		8,000
Value of sewage, every 24 hours (gallons)		12,000,000
Privies "old system"		35,000
Privies "pail system"		7,000
Ashpits		25,000
Yearly cost of cleansing privies for 1875		£35,180
Refuse (128,512 tons) sells for		£5,885

The borough has been sewered at a cost of about 250,000*l*., the sewage gravitating to a point at Saltley. In the first instance it was discharged direct into the river Tame, a small stream, which at a few miles from the works flowed through the estates of Sir Charles Bowyer Adderley, K.C.M.G., M.P. He complained of the nuisance caused in the river by the sewage, and in 1858, on his application, an injunction was granted by the Court of Chancery to restrain the corporation from discharging sewage into the Tame, but the Court granted time in which the corporation were to construct works to abate the nuisance. The corporation caused subsidence-tanks to be constructed near the main sewers outfall and the sewage to be diverted from the river; processes of sand-filtration, and also of upward-filtration were tried but were abandoned.

In 1861, the corporation purchased, at a cost of 8,000*l*., 28¼ acres of land in order to obtain access to canal and railway, and for affording additional facilities for dealing with the mud arrested in the tanks. In 1866, Sir Charles Adderley again complained of the state of the river, and the corporation, in 1867, took on lease 128 acres of land in addition, at a yearly rent of 855*l*. with the object of cleansing a portion of the sewage by irrigation. They caused this farm to be levelled, laid out, and drained, and the necessary roads and bridges constructed at a cost of 11,250*l*., or at a rate of 75*l*. per acre, but, in 1870 Sir Charles

Adderley again invoked the aid of the Court of Chancery, and obtained an order of sequestration.

About the same date certain other owners of property near the subsidence-tanks also moved the Court to hinder the corporation from depositing on the ground sewage-sludge arrested in the tanks and the Court, in this case also, granted the injunction prayed for. Whereupon the council either removed the sludge or dug it into a portion of the farm-lands. Thus restrained on all sides, instructions were given to the borough surveyor, early in 1871, to submit surveys and levels of any lands he considered most suitable for dealing with the sewage by irrigation, and to employ such assistance as he considered necessary. In June of that year a comprehensive report was jointly prepared by Messrs. Blackburn, J. Chalmers Morton, Lawson, and Mansergh, and Doctors Voelcker and Hill, recommending the taking 2,000 to 2,500 acres of land near Kingsbury, about eight miles below the present outlet, and the construction of sewage-conduits for conveying the sewage thereto. This report was laid before the council, but the scheme being considered too costly, a special committee was instructed to again consider the whole question of sewage disposal, and acting on their advice the corporation promoted a Bill in Parliament in session 1872 to acquire powers to extend the main-sewer to a portion of the land before described at Kingsbury, and there to obtain 800 acres, on which to purify the whole of the sewage, partly by intermittent downward filtration, and partly by irrigation. The Bill passed through committee of the Commons after a lengthy opposition, but was thrown out on the third reading. The costs incurred to the corporation in promoting this Bill amounted to 10,644*l.* 7*s.* 10*d.*, and not having passed placed the town in a dilemma; however, in order to satisfy the requirements of the Court of Chancery, the corporation purchased 24 acres of land, formerly held on lease, for the sum of 8,000*l.* and subsequently further increased the area of the farm at Saltley by adding to it a purchase of 101 acres, at a cost of 29,400*l.*; acting on the advice of Thomas Hawkesley, Esq., C.E., as to the best method of treating the sewage at the outlet-works (under their limited powers). The town council, in accordance with his recommendations, caused four additional sets of subsidence-tanks to be constructed, and the sewage to be treated by the lime process. A volume of about 12,000,000 gallons every 24 hours is thus, by the addition of 13 tons of lime, to a certain extent clarified and an average of 365 cubic yards, or about 300 tons of the suspended matters of sewage, are deposited in the tanks, or about 110,000 tons per annum. The total cost of the outlet works and tanks has been 58,880*l.* The corporation have permitted Major-General Scott, C.B., R.E., to carry on experimentally his process for treating sewage and converting the "sludge" into cement, but this has not been done to any great extent, because it is not remunerative. The corporation are now making arrangements for carrying the water, clarified by the lime process on to the adjoining lands at Saltley for irrigation and filtration, and it is expected that by these means a more complete purification of the polluted liquid will be effected.

The "sludge," amounting to 365 cubic yards daily from the subsidence tanks, is removed and dug into land, a portion of the farm, at a cost of 14*l.* 10*s.* per acre, at a rate of about one acre per week, or, in the whole, 56 acres during the year. With reference to the suit instituted by Sir Charles B. Adderley, it was in 1875 arranged that the order of sequestration should be discharged, and that the injunction should be varied so as admit of the corporation constructing new sewers within the town which they had been prevented doing for some years, as also that the sum of 6,000*l.* should be paid to Sir Charles Adderley in settlement of

damages, costs, and all claims to the date of order; and that all proceedings in the cause should be stayed for five years from the date of order, on the corporation undertaking "not to construct new sewers too quickly."

The liquid sewage only represents a portion of the fæcal waste of the inhabitants, as a considerable portion of the solid excrement, mixed with urine and ashes, is received into the 35,000 old privies and 25,000 ash-pits. There are also the 7,000 privies constructed on the "pail system," distributed over the borough, and the contents of these receptacles have to be dealt with by the scavenger, and last year (1875) 128,512 tons of this refuse were removed and sent to country depôts to be afterwards disposed of to farmers. Statements of income and expenditure on sewage farm, outlet and interception works, also on Major-General Scott's cement process, and further on the collection and disposal of excreta and house waste and ashes for the year 1875, and an approximate estimate for these services for the present year are given below, together with results of analysis of a sample of the effluent water flowing to the farm during March 1875.

INCOME and EXPENDITURE for the year 1875.

Income.	£	s.	d.	Expenditure.	£	s.	d.
Interception Department: Amount received for contents of privies and "pails" - -	5,885	0	0	Interception Department: Expense of cleansing and removing contents of privies and "pails" - -	35,180	0	0
Outlet Department: Amount received for sale of a portion of sludge -	202	10	0	Outlet Department: Expense of cleansing tanks, removing and disposing sludge -	12,778	0	0
Major-General Scott's cement process - -	179	0	0	Major-General Scott's cement process -	332	0	0
Farm produce sold -	2,130	0	0	Working expense of farm	2,547	0	0

Borough Surveyor's Office, Birmingham,
January 24th, 1876.

ESTIMATES of INCOME and EXPENDITURE for the year 1876.

Income.	£	s.	d.	Expenditure.	£	s.	d.
Interception Department: Amount received for the contents of privies and "pails" - -	7,000	0	0	Interception Department: Expense of cleansing and removing contents of privies and "pails" - -	36,190	0	0
Outlet Department: Amount received for sale of a portion of sludge -	200	0	0	Outlet Department: Expense of cleansing sludge-tanks, removing and disposing sludge - -	12,825	0	0
Major-General Scott's cement process - -	150	0	0	Major-General Scott's cement process -	300	0	0
Farm produce sold - -	2,550	0	0	Working expenses of farm	2,960	0	0

Borough Surveyor's Office, Birmingham,
January 24th, 1876.

Chemical Laboratory, Corporation Sewage Works, Birmingham.—Certificate—Sample of effluent water from new precipitating tanks at above, taken March 1875.—Examined for general impurities.—Copy; January 26th 1876.

	Grains per Imperial gallon.
Total solid residue containing	58·10
Mineral matter	57·10
Volatile matter	7·00
Suspended matter	1·68
Soluble matter	49·42
Silica	0·84
Alumina, oxide of iron, and phosphates	0·14
Lime	12·22
Sulphuric acid	17·38
Chlorine	9·52
Free ammonia	1·218
Albuminoid ammonia	0·042
=disintegrated animal refuse	0·420
Appearance	Clear.
Smell	Slightly ammoniacal
Action on test paper	Alkaline.

Owing to the construction of new tanks and other works, as well as the large area of land used for digging in the "sludge," the farm is much sacrificed. The valley, too, in which it is situated is an excessively cold one, consequently market gardening does not answer, the crops being late. Italian-rye-grass has been found to yield the best result; but the demand for this produce has not been large.

Notwithstanding the expense incurred by the corporation in clarifying their sewage prior to its discharge into the river Tame, the sewage of adjacent townships, with large and rapidly increasing populations, is being poured daily into the Tame, or into its tributaries, without any attempt at clarification. Recently the Council have convened a meeting of representatives of adjacent boards, and at such meeting it was determined to appoint a joint committee to consider and report with reference to the formation of a combined drainage district.

BOLTON-LE-MOORS.

The borough of Bolton has a rateable value of 311,563*l.* and a population of about 93,100, inhabiting 18,249 houses, which are spread over an area of 2,002 acres. There are only about 758 waterclosets, and the fæcal matters of the population are chiefly disposed of by the 10,380 "middens," and 700 privies on the "pail" system. The "middens" are drained into the sewers, consequently no inconsiderable portion of the solid excrement, partly in solution and partly in suspension, drains into the sewerage system. The borough has been sewered, but the whole of the sewage has not been intercepted, as four of the principal connexions between the main-sewers on each side of the Croal have yet to be made. The cost of the works up to this date (January 1876)

has been about 70,000*l.* The rainfall from the roofs of buildings and surface of streets ordinarily flows into the sewers, but in heavy storms the flood water is discharged by 18 storm-outlets direct into the river.

Before any intercepting sewers were constructed, the sewage flowed by about 100 outlets direct into the river, causing a nuisance and serious annoyance to the inhabitants living adjacent and near to the Mill Lodge of the Springfield paper-works. A memorial having been presented to Mr. Secretary Bruce by the owners and occupiers of property (being ratepayers) in the township of Bolton, he directed an inquiry, under the 29th and 30th Victoria, chapter 90, section 49, "as to the "alleged default of the corporation of Bolton in not having provided its "district with proper sewers, and polluting the river Croal." This inquiry was held on 19th August 1868 by Mr. Arnold Taylor, one of the inspectors of the Local Government Act Office. On receipt of his report, dated 17th December 1868, the Secretary of State directed that a copy of it should be sent to the corporation. After the lapse of nearly a year, no decisive steps having been taken in the meantime to abate the nuisance complained of, the Secretary of State directed (28th June 1869) that the plans and estimates of the borough engineer of Bolton (Mr. J. Baylis), in reference to the diversion of the sewage of the borough from the river Croal, together with any alternative plans that may have been prepared by instructions of the town council be sent to the Local Government Act Office for approval without further delay. These plans and estimates were submitted and approved, but a further delay having taken place in carrying out the works, the Secretary of State, being satisfied that the town council had been guilty of default, issued an order under his hand the 21st day of July 1869, directing that the works necessary for the diversion of the sewage should be commenced within 14 days from the date of the order, and that the works so commenced should be continued without intermission until completion. The intercepting sewers which have been constructed have cost 10,286*l.* In June 1870 the corporation entered into an agreement with the "A. B. C. (Native Guano Company)," whereby they contracted to erect works at Burden, near the southern boundary of the borough, at a cost of 16,578*l.*, and the company, on their part, undertook to defæcate and purify the sewage, so as to render it fit to be admitted into the river; and in consideration for the use of the patents of the company, the corporation agreed to pay the working expenses of the process, and to deliver to the company one-fourth part of the manure manufactured at the works from the sewage-sludge. The volume of sewage which flows to the works every 24 hours is about 2,500,000 gallons; but, in addition to this, there is a further volume of 1,000,000 gallons also intercepted, which is at present discharged by one outlet into the river, as the four syphons under the river to connect this sewer with the main outfall are not finished. There is also an additional volume of about 500,000 gallons of sewage yet to be intercepted, which now passes by several outlets direct into the river.

The A. B. C. process was carried on up to June 1873, but was then abandoned, owing to the great expense of working it, and also because the manure manufactured from the sludge could not be sold.

We were furnished by the manager of the works (27th January 1876) with the cost of labour and materials required to treat 1,035,000 gallons (about half the present daily flow of the sewage of Bolton,) for a period of 57½ hours by the A. B. C. process, *i.e.*)

	£	s.	d.
Manager (Mr. Graham). Salary -	2	17	$3\frac{1}{2}$
Engine driver. (Wages.) - -	1	10	0
Alum preparer. Do. - - -	1	4	0
Mixture grinder. Do. - - -	1	2	0
4 Labourers, each 1*l.* 1*s.* 0*d.* (Wages) -	4	4	0
Watchman on Sunday - - -	0	2	0
Extra for overtime - - -	0	8	0
71 cwt. of sulphate of alumina, at 1*s.* $8\frac{1}{2}$*d.* per cwt. - - - -	6	1	4
132 cwt. of clay, at 4*s.* per ton - -	1	6	2
81 cwt. of carbon (waste product of prussiate of potash manufacture) - -	1	4	$3\frac{1}{2}$
Blood - - - - -	0	1	0
8 tons of engine coal, 7*s.* 6*d.* per ton -	3	0	0
Oil, tallow, packing, &c. - - -	0	6	0
Water and gas - - - -	0	12	0
	£23	18	1

To this amount must be added contingencies and the cost of repairs to and deprecation of works and plant. (See also special report on this process by the Rivers Pollution Commission, 1870). The corporation have not been required (up to this date 27th January 1876) to deliver any manure to the order of the patentees, but there is, and has been for the last two years, stored at the works awaiting the order of the company 700 tons of this manure. The sewage is now only treated from 8 a.m. to 6 p.m. on week days and not at all on Sundays, and the whole of the sewage from 6 p.m. to 8 a.m. flows on Snndays untreated direct into the river. The process now used is also a patent one, known as the M. and C. method, and it was stated to us to be identical with the process of Mr. Goodall, which had been tried at Leeds. In carrying out the M. and C. process there is added to the sewage to be purified a mixture consisting of the following ingredients: lime, carbon (a waste product of the prussiate of potash manufacture), house ashes, soda, and per-chloride of iron. The materials are mixed in a "pit" and lifted therefrom by means of a dredger into a second mixing pit, from which the mixture is discharged slowly into the sewage as it flows through the works into two depositing tanks, each divided into three compartments, after which the treated sewage flows for a short distance along an open conduit and thence into the River Croal. The tanks are cleaned out every fortnight, and about 70 tons of "sludge" are removed therefrom and thrown into heaps at the side of the tanks to part with the moisture which it contains, but it has been found impossible to dry it without applying artificial heat. The cost of working the M. and C. process is stated by the manager to be less than that of the A. B. C. process, and we here append the statement which he supplied to us:

"To the chairman and members of the Bolton Corporation Investigation Committee.

"Bolton Corporation Sewage Works,
January 14th, 1875.

GENTLEMEN,

I BEG to submit to you a statement of the cost for labour and materials required for the treatment of 2,500,000 gallons daily of sewage-water for a period of $57\frac{1}{2}$ hours, (*i.e.*, 10 hours for five days, and $7\frac{1}{2}$ hours for one day in the week."

Cost of treating Sewage by the M. and C. process.

	£	s.	d.
Wages, &c. per week - - -	2	14	0
One labourer, preparing mixture, &c. -	1	6	0
Two „ at 1*l.* 2*s.* each - -	2	4	0
Two „ at 1*l.* 1*s.* do. - -	2	2	0
Extra for overtime - - - -	0	5	0
Lime, 7 tons 3 cwt., at 18*s.* 6*d.* per ton -	6	12	3
Refuse carbon, 2 tons 15 cwts., at 6*s.* per ton - - - - -	0	16	6
Salts, &c. - - - - -	0	15	0
Coal, 5 tons at 7*s.* 6*d.* - -	1	17	6
Oil tallow packing, &c. - - -	0	5	0
Water and gas - - - -	0	10	0
	£19	7	3"

It will be observed that this volume of 2,500,000 gallons of sewage is the daily flow to the works, and that when the intercepting sewers are completed, the volume will be augmented to about 5,000,000 gallons, and as the works have been constructed for treating only 3,000,000 gallons a day of 10 hours, they will have to be considerably enlarged.

In February and April 1873, the corporation sold to Mr. John Higginbotham of Manchester, 50 tons of the manure manufactured by the A. B. C. process at 55*s.* per ton, but the persons to whom he afterwards sold it, complained of the quality of it, and he refused to pay for it, and the corporation had to commence proceedings against him to recover the amount.

The sewers in the town are ventilated by open grids in the manhole covers and also by 228 separate shafts carried up from the sewers to the surface of the streets and covered by open grids.

Besides the yearly cost of dealing with the present limited volume of liquid sewage, there is the further expense of cleansing the 10,380 "middens," the 700 privies on the "pail" system, and the yearly cost of this is 6,645*l.*, but this is not all loss as the corporation receive for 51,290 tons of refuse removed from these receptacles, 4,494*l.*

The corporation in order to get rid of the sludge caused some of it to be mixed with the refuse from the middens, and have sold 100 tons of this mixture at 1*s.* per ton. There is, however, about 2,500 tons of the prepared sludge now lying at the works.

The M. and C. process, like its twin the A. B. C. process, merely removes the grosser parts of the suspended matters in sewage, but fails to remove the putrescible organic matters in solution, and therefore the clarified sewage cannot be admitted into rivers without causing pollution, this is conclusively proved by the following result of analysis of a sample of the effluent water by Dr. Henry E. Roscoe, F.R.S., Professor of Chemistry, the Owens' College, Manchester, which has been furnished to us by the town clerk.

The Owens' College, Manchester,
To the Town Clerk of Bolton. January 22nd, 1874.

Sir,

" I beg herewith to send you results of careful analysis (1) of effluent water and (2) of manure, sent from the sewage department of the borough of Bolton by Mr. John Forster on the 27th of December last."

(1) Effluent Water.

	Grains per gallon.	Parts per 100,000.
Total residue - - - -	62·65	89·5
Loss on ignition - - -	5·25	7·5
Nitrogen as nitrites and nitrates -	0·23	0·3292
Free ammonia - - - -	1·75	2·5
Albumenoid ammonia - - -	0·448	0·64
Chlorine - - - -	4·20	6·00
Temporary hardness - - -	16·2°	—
Permanent „ - - -	20·0°	—
Total „ - - -	36·2°	—

"As regards the results of this analysis it appears that the water, as compared with London sewage, contains about half as much animal refuse or products of animal decomposition. As regards the inorganic portion, this water contains considerably more than the London sewage does. These animal impurities are not completely got rid of by oxidation: and, on keeping, the water has a putrescent smell, it cannot therefore be said that the process, whatever it may be that the sewage has undergone, has done much to render the effluent water innocuous."

(2) The Manure.

Total nitrogen - - -	0·76°/o
Insoluble phosphate - - -	0·93°/o
Soluble phosphate - - -	None.
Moisture - - - -	26·67°/o
Loss on ignition - - -	49·80°/o

"From the preceding analysis of the manure in which I have only determined the constituents of importance, it will be seen that the quantity of total nitrogen and phosphates is so small that the value of the manure is certainly not greater than 1*l.* per ton.

"I am &c.,

"(Signed) Henry E. Roscoe.

"To the Town Clerk, Bolton-le-Moors."

We collected a sample of the sludge of the M. and C. process, and caused it to be analysed by Dr. A. Voelcker, F.R.S.

Results of analysis of sample of the sludge from the M. and C. process carried out at Bolton-le-Moors.

This sludge in the condition in which it was received by me contained in 100 parts—

Water - - - - - -		60·83
*Organic matter - - - - -		14·66
Oxide of iron and alumina - - -		3·81
Tribasic phosphate of lime - - -		0·69
Carbonate of lime - - - -		8·18
Sulphate of lime - - - - -		0·59
Alkaline salts, magnesia - - - -		1·70
Containing potash - -	0·30	
and chloride of sodium - -	0·04	
Insoluble siliceous matter (sand and clay) -		9·54
		100·00

* Containing nitrogen - - -	0·41
Equal to ammonia - - -	0·49

In the sample of Bolton sludge there is in a ton :	s.	d.
$15\frac{1}{2}$ lbs of phosphates, which at 1*d.* per lb. are worth - -	1	$3\frac{1}{2}$
$6\frac{7}{10}$ lbs. of potash ,, 2*d.* ,, - -	1	1
Nitrogen equal to 11 lbs. of ammonia which, calculating ammonia at 8*d.* per lb., is worth - - - -	7	4
Total estimated money value of 1 ton of Bolton sludge - -	9	$8\frac{1}{2}$

If the sludge were dried sufficiently to leave only 15 per cent. of moisture in the material it would have the following composition :

Moisture - - - - - -		15·00
*Organic matter - - - - - -		31·82
Oxide of iron and alumina - - -		8·52
Tribasic phosphate of lime - - -		1·49
Carbonate of lime - - - -		17·75
Sulphate of lime - - - - -		1·27
Alkaline salts and magnesia - - -		3·68
Containing potash - -	0·64	
and chloride of sodium - -	0·08	
Insoluble siliceous matter - - -		20·47
		100·00

*Containing nitrogen - - -	0·89
Equal to ammonia - - -	1·08

A ton of Bolton sludge dried to that extent contains :	£	s.	d.
33 lbs. of phosphate of lime, worth at 1*d.* per lb. - -	0	2	9
14 lbs. of potash ,, 2*d.* ,, - -	0	2	4
Nitrogen equal to 24 lbs. of ammonia, at 8*d.* per lb. -	0	16	0
Total estimated money value of 1 ton of dried Bolton sludge	£1	1	1

For selling value, see page lxiii.

The cost to dry the sludge is not given ; but experience indicates that the money expended would be wasted, as dried sand and earthy material has no greater value than when wet. There is less weight to cart and that is all.

BRADFORD.

Area - - - - - -	(acres)	7,221
Population, about - - - - - - -		173,723
Rateable value - - - - - - -		£745,671
Sewerage works cost - - - - - -		£70,000
Sewage defæcation works cost - -		£60,000
Waterclosets about - - - - - -		4,050
Daily dry weather volume of sewage -	(gallons)	8,000,000
The cost of defæcating sewage (1875) - - -		£8,000
Privies - - - - - - - - -		11,500
Ashpits - - - - - - - - -		16,500
Yearly cost of cleansing privies and ashpits - -		£8,000
Quantity of refuse removed yearly - - -	(tons)	56,200
First cost of railway waggons for conveying refuse -		£4,800

The borough of Bradford has been sewered at a cost of 70,000*l.*, and the 4,050 waterclosets and 11,500 privies and cesspits used by its 173,723 inhabitants are drained into the system which comprises about 48 miles of main and tributary sewers. The main sewerage works were commenced in 1862 and finished in 1875. In 1868 the entire volume of sewage

(about 8,000,000 gallons per day) flowed direct into the Bradford Beck, then a black and offensive stream. The Rivers Pollution Commission designated it "the most filthy stream they had met with, surpassing the "worst examples in Lancashire." Although the sewage was not worse in appearance than the water of the "Beck," into which it flowed, Mr. William Crompton Stansfield of Esholt Hall, near Apperley Bridge, considered himself aggrieved by the additional pollution which the sewage caused to the stream, and on the 28th of August 1868, he filed a Bill of Complaint in the Court of Chancery to restrain the corporation from causing or permitting to pass any sewage, filth, or other offensive matter, solid or liquid, into the Bradford Beck in such a manner that the same might pass therefrom into the river Aire to his injury, and prayed that damages might be awarded for all injuries suffered. On the 1st September 1868, the corporation was served with an interim injunction obtained ex parte from the Master of the Rolls, prohibiting them under a penalty of 10,000*l.* from opening or permitting to be opened any additional main or branch-sewer, or any house-drain or sewer into the outfall-sewer or into the Bradford Beck, or any sewer communicating therewith or emptying itself therein. An answer to the bill was filed, but negociations between the corporation and the Plaintiff ended in an arrangement whereby the injunction was dissolved upon terms, one of which was that the corporation should, on or before the 11th of January, take steps to defæcate the sewage passing through the public sewers. The corporation being convinced that any works merely dealing with the sewage of the town would fail to produce any appreciable improvement in the condition of the river Aire, they, in conjunction with other corporations and local boards in the watersheds of the Aire and Calder, introduced a Bill into Parliament during the Session of 1871 called the "Aire and Calder Conservancy Bill," which proposed to deal in a comprehensive manner with the sewage of the two watersheds. Violent opposition to this Bill was threatened, and it was consequently withdrawn. The same year the "Peat Engineering and Sewage Filtration Company," made an offer to the corporation to apply their system to the sewage of Bradford. Arrangements were made by which the corporation agreed to lease the sewage to this company for a term of 21 years, and to provide lands and buildings in which the operations were to be carried on; and the Company, on their part, agreed to purify the sewage, estimated at a daily volume of 8,000,000 gallons at their own expense, the residuum to become the property of the company. The company were also to have free use, for the first three years, of the buildings and plant to be constructed by the corporation; but after that period they were to pay the corporation a rent for the use thereof. These works were subsequently erected at a cost of 60,000*l.*, including land and incidental expenses. The company however failed to carry out the contract, and legal proceedings were commenced by the corporation against the company and their sureties to enforce the contract; but the company collapsed, and the corporation in 1874 took possession of the works.

The defæcation works are situate in a valley between Frizinghall and Massingham, and were specially constructed for carrying out the process of filtration by peat charcoal. This process failed, because the sediment, choked the filters; and as the filtering medium required to be constantly replaced, the cost was ruinous, and the process had consequently to be abandoned. The corporation then made such alterations to the works as to carry on a combined process of precipitation and filtration; and this method has for some time past been in operation for defæcating the sewage, which gravitates to the works, and flows into four subsidence tanks, from these tanks it passes along an

open conduit, across which iron screens are fixed to hold back any flocculent matters. Below the floor of the building, which is 700 feet long and 32 feet wide, there are 22 tanks, each tank 30 ft. × 32 ft. × 9ft. deep, and these, with the exception of the two middle ones, are used as precipitation tanks for the sludge. At the deepest point of these tanks connexions are made to a 9-inch cast-iron sewer pipe, through which the sediment is passed to "sludge-pits," one at each end of the building. The two middle tanks receive sewage from an "open conduit," and the coarser particles subside. After flowing through these tanks, lime, in the state of "milk of lime," is mixed with the sewage, which then flows along another open conduit into other precipitation tanks, of which there are 34. These tanks are each 22 feet wide by 24 feet long, and of an average depth of 5 feet, and are capable of holding about 18,000 gallons each, or together 612,000 gallons. The bottom of the tanks slope towards the filters, and after the sewage has been allowed to subside from 20 to 30 minutes, the supernatant liquid passes through a self-acting float-valve on to 34 filters; these are each 22 feet long by 12 feet wide by 2 feet deep, and are filled with coke. From these filters the clarified water passes into another open conduit, called the "effluent canal;" this runs along the entire length of the filter tanks, and is also partly filled with coke, and from this canal the treated sewage flows into the Bradford Beck. The sewage is allowed a period of from 20 to 30 minutes for subsidence in each tank, and as it only takes 15 minutes to fill a tank and 15 minutes for the clear liquid to run off, each tank, as constructed, is capable of defæcating 18,000 gallons per hour, and the 34 tanks 612,000 gallons per hour. The "sludge" from the tanks flows through a sewer to the sludge-pits, situate at either end of the main building; from these pits it is pumped into the tanks under the building, where it has an opportunity of parting with a portion of its moisture, and is thence removed to open sheds; and although it is there exposed to the air, it only loses a small quantity of its water, and the corporation propose to adopt artificial means to dry the sludge, of which about 22 tons are daily produced from the sewage of the town. The works have a railway siding to the Midland Railway on the one side, and are bounded by the Leeds Canal on the other, so that great facilities are afforded for the removal of the manure.

The quantity of lime required for precipitation of the sewage is one ton to every million gallons of sewage, but on Sundays, when the sewage contains no dye water, half a ton to every million gallons is found to be sufficient. The mixing and other machinery is at present driven by three portable steam engines of 10-horse power each, one in the centre of the building and one at each end.

The estimate for defæcating the sewage for the year 1876 is as follows:—

"*Salary and Wages.*"

	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*
Manager (G. Alsing) -	-		-	300	0	0			
Foreman (James Lees) per week	2	2	8	109	4	0			
Night do. (John Duxbury) do.	1	10	0	78	0	0			
1 joiner do.	1	12	0	83	4	0			
6 engine tenters (each) do.	1	5	0	390	0	0			
18 labourers (day), with extra time, say 61 weeks do.	1	4	0	1,317	12	0			
10 do. night do. do.	1	4	0	732	0	0			
							3,010	0	0

Brought forward -				£3,010 0 0

"Materials and Miscellaneous Expenses."

	£	s.	d.	
3,000 tons of lime - - -	1,875	0	0	
2,000 tons of breeze for filters - -	125	0	0	
1,040 tons of coke for fuel - -	637	0	0	
5 tons of coals - - - -	5	0	0	
Gas - - - - -	120	0	0	
150 gallons of engine oil - -	32	10	0	
224 lbs. cotton waste - - -	6	10	0	
220 lbs. candles - - - -	5	10	0	
Timber for keeping up plant, machinery, and buildings - - - -	50	0	0	
Repair of engines, machinery, &c. -	50	0	0	
Alterations and additions - -	100	0	0	
Office requisites - - - -	10	0	0	
Rates, taxes, and sundries - -	250	0	0	
				3,266 10 0
				£6,276 10 0

The corporation has not as yet been enabled to sell any of the sludge which consequently accumulates at the works.

In addition to the cost of defæcating the sewage, the annual cost of cleansing the 11,500 privies and 16,500 ashpits is 8,000*l.*, and the whole of the refuse removed therefrom becomes the property of the contractor and is disposed of by him.

Abstract.

	£	s.	d.
Annual cost of treating sewage - - -	£6,276	10	0
Annual cost of cleansing privies - - -	8,000	0	0
Total - - - - -	£14,276	10	0

We collected samples of the solids extracted from the sewage before, and also of the sewage-sludge after treatment, and the following are the results of Dr. Voelcker's analyses.

Sludge from drying pits, no artificial heat being used.

On analysis the sludge as received, and calculated with 15 per cent. of moisture, furnished the following results:—

				Calculated with 15 per cent. of moisture.
Water - - - - - -		82·41		15·00
*Organic matter - - - -		7·54		36·44
Oxide of iron and alumina - - -		0·78		3·77
Tribasic phosphate of lime - - -		0·69		3·34
Carbonate of lime - - - -		5·66		27·36
Sulphate of lime - - - -		0·49		2·36
Alkaline salts and magnesia - - -		0·73		3·52
Containing—Potash - -	0·16		0·77	
and chloride of sodium - -	0·11		0·52	
Insoluble siliceous matter - - -		1·70		8·21
		100·00		100·00

* Containing nitrogen - - - -	0·14	0·67
Equal to ammonia - - - -	0·17	0·81

	£	s.	d.
In a ton of the wet sludge there are $17\frac{1}{2}$ lbs. of phosphate of lime, worth at 1*d.* per lb. - - - -	0	1	$5\frac{1}{2}$
$3\frac{1}{2}$ lbs. of potash worth at 2*d.* per lb. - - -	0	0	7
Nitrogen equal to 4 lbs. of ammonia at 8*d.* - - -	0	2	8
Total estimated money value of 1 ton of wet sludge	£0	4	$8\frac{1}{2}$

	£	s.	d.
The dried sludge contains in 1 ton 75 lbs. of phosphate of lime, worth at 1*d.* per lb. - - - -	0	6	3
$17\frac{1}{4}$ lbs. of potash, worth at 2*d.* per lb. - - -	0	1	$10\frac{1}{2}$
Nitrogen equal to 18 lbs. of ammonia at 8*d.* per lb. -	0	12	0
Total estimated money value of 1 ton of dried sludge	£1	0	$1\frac{1}{2}$

For the selling value, see page lxiii.

Solids drained from Sewage before the Liming Process at Bradford.

A sample received in a partially dried condition had the following composition:—

				Calculated with 15 per cent. of moisture.
Water - - - - - -		51·41		15·00
* Organic matter - - - -		23·94		41·88
Oxide of iron and aluminia - - -		2·63		4·61
Tribasic phosphate of lime - - -		0·69		1·21
Carbonate of lime - - - -		4·07		7·11
Sulphate of lime - - - -		0·42		0·73
Alkaline salts and magnesia - - -		1·28		2·24
Containing—Potash - -	0·47		0·82	
and chloride of sodium - -	0·03		0·05	
Insoluble siliceous matter - - -		15·56		27·22
		100·00		100·00
* Containing nitrogen - - - -		0·44		0·77
Equal to ammonia - - - -		0·53		0·93

According to the preceding analytical results the sample with 51·41 per cent. of moisture contains in 1 ton—

	£	s.	d.
$15\frac{1}{2}$ lbs. of phosphate of lime, worth at 1*d.* per lb. - -	0	1	$3\frac{1}{2}$
$10\frac{1}{2}$ lbs. of potash „ 2*d.* per lb. - -	0	1	9
Nitrogen, equal to 12 lbs. of ammonia at 8*d.* per lb. -	0	8	0
Making a total estimated value of 1 ton - -	£0	11	$0\frac{1}{2}$

The same material with 15 per cent. of moisture contains in a ton—

	£	s.	d.
27 lbs. of phosphate of lime, worth at 1*d.* per lb. - -	0	2	3
18 lbs. of potash „ 2*d.* per lb. - -	0	3	0
Nitrogen equal to 21 lbs. of ammonia at 8*d.* per lb. -	0	14	0
Total estimated value of 1 ton - - -	£0	19	3

For the probable value, see page lxiii.

COVENTRY.

Area (acres)	1,600
Population (about)	40,000
Rateable value	£101,438
Inhabited houses	10,400
Waterclosets	5,000
Cost of the main sewerage works	£33,000
Volume of sewage every 24 hours, about (gallons)	2,000,000
Privies	800
Cost of cleansing privies (yearly)	£1,050

Cost of farm for sewage irrigation, 27,000*l.* The farm has been let in consequence of the offer from the "General Manure and Sewage Company, Limited," freeing the corporation (for the time) from the responsibility of purifying the sewage.

The city of Coventry has been sewered; the works were commenced in 1853 and finished in 1855, at a cost of 33,000*l.* The whole of the sewage flows to one outfall at Whitley into the river Sherbourne, which is a small and rather sluggish stream. There are in the city 10,400 houses, and the excrements of the 40,000 persons who inhabit them are conveyed into the sewers by about 5,000 waterclosets, and consequently into the river into which the sewers discharge themselves, as there are only 800 privies. The sewers are ventilated by open grids in the covers of the 500 manholes, which are formed on the lines of sewers; they are also ventilated by being connected to fourteen factory chimney shafts, and further by the rain-water stacks from the eaves of houses. The whole of the rain-fall on the roofs and surface of the streets flows into the sewers, and from thence in heavy storms into the river by an overflow outlet specially provided for that purpose situate near Shut Mill Lane. Several springs were tapped while the sewerage works were being constructed, and a volume of about 500,000 gallons from this source enters the sewers daily. The waterworks belong to a private company, and 720,000 gallons of potable water are daily delivered for the use of consumers. There are also 21 public wells and a great many private wells from which a considerable number of the inhabitants obtain water for domestic purposes.

In 1860, complaints having been made by riparian owners of the pollution caused to the river Sherburne, the corporation directed subsidence tanks to be constructed near the river, and the outfall to be diverted so that the sewage might be discharged into the tanks, and afterwards filtered through a medium of gravel 3 feet in thickness before it entered the river. The tanks and so-called filters were a failure as regards purifying the sewage; they only partially extracted the suspended matters, and left the putrescible organic matters in solution, and although this somewhat mitigated the nuisance, it did not produce any substantial diminution of the polluting quality of the liquid.

Further complaints having been made of the condition of the river, the corporation, as advised in 1869, purchased 262 acres of land at Whitley at a cost of 27,000*l.*, and instructed Mr. T. Hawkesley, M. Inst., C.E., to prepare a scheme for laying it out as an irrigation farm; and he subsequently submitted plans and an estimate of the proposed works. The sewage would, owing to the configuration of the land, have to be pumped on to the farm, and this circumstance, in addition to the great cost of the proposed works, caused the corporation to postpone carrying out the scheme. In August 1870, the A. B. C. or "Native "Guano Company," made an offer to the corporation to treat the sewage of the city by their process, but the terms proposed by the corporation

were not accepted by the company. On the 25th September 1871, Mr. H. M. Jackson, a riparian owner, filed a bill of complaint in Chancery and applied for an interlocutory injunction to restrain the corporation from passing sewage into the river, but the court declined to grant the injunction and the suit was abandoned.

In 1872, the "Peat Engineering and Sewage Filtration Company," made an offer to the corporation to deal with the sewage by their process, but this offer the corporation did not entertain.

On the 25th of October in the same year, the corporation entered into a contract with the "General Sewage and Manure Company, Limited," whereby a messuage and 28 acres of land at the outfall works were leased by the corporation to the company for 14 years at a rent of 75*l.* per annum, together with the sewage of the city. The company covenanted to erect the necessary buildings; to furnish the requisite machinery and plant; to effectually deodorize and purify the whole of the sewage of the city, and to pass the clarified water therefrom into the river Sherburne, and they further covenanted that if default is made, after six weeks' notice, in carrying out the conditions of the lease, the corporation shall have power of re-entry and to put an end to the lease; whereupon all buildings and works shall become the property of the corporation without payment or compensation to the company; and the corporation are also to have the option of buying the steam engines, machinery, and other effects on the works at a valuation.

The company were to commence to treat the sewage on the 29th of September 1873, but it was not until May 1874 that the works were sufficiently completed to enable them to do so.

The "General Sewage and Manure Company Limited" was formed in 1872, with a primary object of working on a practical scale the process for the purification of town sewage patented by Dr. Anderson, but the company have also acquired other patents for improving this process. The works erected by the company at Coventry, at a cost, including machinery and plant, of 12,000*l.*, are situated on the right bank of the River Sherburne about two miles from the city. The sewage, estimated at 2,000,000 gallons every 24 hours, is weak owing to the large volume of subsoil water which mingles with it on its passage through the sewers. On the sewage reaching the works it passes through "extractors" which remove the coarser parts of the suspended matters, and it then flows into circular mixing tanks, constructed beneath the floor of the first block of buildings, to these tanks are affixed "agitators" driven by steam power for thoroughly mixing the compound which is here added to the sewage in such quantities as from time to time is required. This mixture consists of a saturated solution of crude sulphate of alumina, which has been heated to the boiling point, and this is prepared at the works from ordinary clay, or from shale of the coal measures, treated with concentrated sulphuric acid (an aluminous shale is at present used). From the mixing pits the sewage flows into another series of tanks under the floor of the second block of buildings, and in these tanks "lime" in the condition of so-called "milk" is added to the sewage which is here also continuously agitated by machinery."

From the "liming-tanks" the defæcated sewage flows into uncovered subsidence-tanks; these are four in number, and each tank is cleaned out every fourth day. The supernatant liquid flows from these tanks in a tolerably clear condition into a conduit which discharges it on to an area of about 4½ acres of loamy soil adjoining the works. This land has been roughly laid out as a land-filter and drained about five feet deep with an outlet at the extreme end of the land into the river Sher-

borne. On the date of our visit to the works the effluent water flowing from this outlet was clear and inodorous. The sludge precipitated into the tanks amounts to about 30 tons daily, and this, after being passed through a further straining process, is placed in heaps at the works to lose a still further portion of its moisture. We observed a large accumulation of this deposit. In order to convert the semi-dried sludge into a manure it is further dried by artificial heat by the use of Messrs. Milward's sewage mud-drying machines.

The company treat by their process the sewage flowing to the works between the hours of 5.30 a.m. and 11 p.m., but the sewage of the night (*i.e.*, from 11 p.m. to 5.30 a.m.) flows through the tanks, and on to the filtering area without chemical treatment. The company say that the sewage during that period is chiefly subsoil water, and it only needs to be passed through the tanks mixed with the chemically treated sewage which they contain, and then flow on to the filter beds."

By the courtesy of Messrs. J. C. Melliss and E. F. Coddington, the engineer and the manager of the works, we are enabled to give the working expenses of the company.

WORKING EXPENSES, WEEKLY.

	£	s.	d.
22 tons of coal, at 10*s.* 6*d.* per ton - - - -	11	11	0
27 cwt. of sulphuric acid, at 76*s.* 6*d.* per ton - -	5	3	3
9 tons of sulphate of alumina, 27*s.* 6*d.* per ton - -	12	7	6
4½ tons of lime, at 16*s.* 2*d.* per ton - - - -	3	12	9
Labour (12 men) - - - - - -	16	0	0
Contingencies - - - - - -	1	5	6
	50	0	0

This amounts yearly to a sum of 2,600*l.*; to this must be added the salary of the manager, 250*l.*, and also a sum for repairs and depreciation of works and plant, also the interest on capital expended, say 600*l.*, per annum.

Abstract.

Annual cost of treating the sewage - - -	£2,600	0	0
Manager's salary - - - - -	250	0	0
Interest on capital expended - - - -	600	0	0
Total - - - - -	£3,450	0	0

There is difficulty in getting rid of the sludge, as also of selling the manure when manufactured, but in January of this year (1876) owing to the exertions of the bailiff of the company's farm, the farmers in the neighbourhood have purchased and given orders for 350 tons; of the sludge to be taken direct from subsidence-tanks at 3*s.* per ton, this sludge, costing 4*s.* 10*d.* a ton to produce, when not at once removed, is placed in heaps about the works exposed to the atmosphere, to get rid of some of its water, afterwards if dried by artificial heat it costs in addition 1*l.* 8*s.* 9*d.* per ton, but if there was a demand for the manure, necessitating its being passed through a filter, and also artificial heat being applied to dry it, the cost would be 2*l.* 10*s.* per ton.

The manure thus produced in a dry state is then ground to powder, for sale to farmers.

We collected a sample of the sludge from a heap on the works, and have caused it to be analyzed by Dr. A. Voelcker, F.R.S., and the following are the results.

Analysis of Manure prepared by the General Sewage Manure Company at Coventry.

A sample of the Coventry sewage manure was found of the following composition:—

Moisture - - - - - - -		47·36
*Organic matter - - - - - - -		15·95
Oxide of iron and alumina - - - - -		5·17
Tribasic phosphate of lime - - - - -		1·81
Carbonate of lime - - - - - -		7·32
Sulphate of lime - - - - - - -		1·19
Alkaline salts and magnesia - - - -		2·38
Containing potash - - - -	0·20	
and chloride of sodium - - - -	0·02	
Insoluable siliceous matter - - - - -		18·82
		100·00

*Containing—Nitrogen - - - - - - 0·69
Equal to ammonia - - - - - - 0·84

According to the preceding analytical results 1 ton of the Coventry sewage manure contains:—

	s.	d.
40½lbs. of phosphate of lime, worth at 1*d.* per lb.	3	4½
4½lbs. of potash „ 2*d.* „	0	9
Nitrogen equal to 19lbs. of ammonia at 8*d.* „	12	8
Total estimated money value per ton - -	16	9½

For the value to the farmer, see page lxiii.

These works have, from the first, been carried on at a loss of not less than 1,500*l.* per annum for each million gallons of sewage per day treated; and, apparently, this rate of loss must continue, so long as this mode of treatment is continued.

The Corporation cleanse about 800 privies annually, removing 6,600 loads of refuse, at a cost of 1,050*l.*

LEEDS.

Area - - - - - -	(acres)	22,000
Population (about) - - - - -		285,000
Rateable value - - - - - - -		£945,141
Waterclosets (about) - - - - -		8,000
Main sewerage works cost about - - - -		£240,000
Estimated daily volume of sewage (about)	(Gallons)	12,000,000
Estimated quantity of "sludge" produced daily	(tons)	40

Or about 15,000 tons annually.

Experimental and permanent works for A. B. C. process at the outfall Knostrop, cost - - - -	£47,000
Borwick's machines for drying the mud cost - -	£4,000
Total cost - - - - - - -	£51,000

Annual cost of treating sewage by A. B. C. process -	£15,000
Number of privies (about) - - - -	15,598
Annual cost of cleansing privies and middens - -	£27,000
Amount received for about 80,000 loads of refuse removed	£9,000

The borough of Leeds has been sewered, and the main outfalls were, until 1852, direct into the river Aire. The sewage was then inter-

cepted and conveyed to one outfall at "Knostrop." Waterclosets are connected with the sewers, and the privy cess-pits and ash-middens are also drained into them ; the sewage is however weak as compared with the sewage of London. The Rivers Pollution Commissioners collected samples of the Leeds sewage, flowing from the works at Knostrop, and submitted them to analyses, and in speaking of the result said. "The Leeds sewage contained a large portion of suspended matters; but it was very deficient in soluble fertilizing ingredients, containing only about one third of the proportion present, in average London sewage. This latter circumstance is due partly to the discharge of much slightly polluting water from factories into the sewers, and partly to the circumstance that 'springs were tapped during the execution of the sewerage works.' It is, however, probable that the sewage was exceptionally weak, at the time our sample was collected (1.30 p.m.) since Glasgow, with a daily water supply of more than 50 gallons her head, furnishes sewage twice as rich in fertilizing ingredients as that of Leeds." The nuisance caused to the river by the sewage is aggravated by the entire volume being discharged through one outfall, at Knostrop, and Sir Charles Hugh Lowther, Bart., and Mr. J. T. Leather, riparian owners, whose lands are situated a short distance below the outfall works, filed on the 5th November 1869, a Bill of Complaint in Chancery, and obtained a perpetual injunction to restrain the corporation from polluting the river Aire by the sewage, at Knostrop ; the Court on application of the defendants granted two years from the date of the decree, in which period the corporation were to devise and carry out a scheme for abating the nuisance ; but the time not proving sufficient to enable them thoroughly to investigate the various remedial processes proposed for consideration, they made further applications to the Court, and on three occasions the time was extended, the last extension was to 1st March 1874. In 1870 the A. B. C. or "Native Guano Company" made an offer to the corporation to treat by their process (for a limited period) the sewage discharged from the works at Knostrop, and also to pay the costs of the materials and labour required to carry on the process, provided that the corporation would bear the cost of erecting experimental works and supplying the necessary machinery for the purpose ; this the corporation agreed to do, and the works, fitted with the necessary plant, were erected at a cost of 10,000*l.* The company carried on the process for some time ; but the corporation had no control over the quantity of the chemicals used. On 17th August 1870 an agreement was entered into between the corporation and the A. B. C. Company, by which the corporation undertook to erect permanent works according to plans furnished by the company, for treating the entire volume of sewage (estimated at 12,000,000 gallons daily), and the company, on their part, undertook to be at the expense of successfully purifying and deodorising that volume of sewage, and to manufacture the "sludge" into a manure, and out of any profits from the sale of such manure to pay to the corporation 15 per cent. of the profits. The works were commenced in 1872 and finished in 1875, at a cost of 47,000*l.* Before the completion of the permanent works the company applied to the corporation to release them from the penalties of the contract, and they alleged as a reason for this request that they could not sell the manure which they had already manufactured at the experimental works, and offered, as a consideration for being released, to allow the corporation, without paying royalty, to use all the patents obtained by the company for "treating sewage water and matters." Eventually, the corporation consented to cancel the agreement, and on this being done the A. B. C. Company vacated the works. Some time after Major-General Scott, C.B., and afterwards Mr. Rupert Goodall,

and finally Mr. Sylvester Fulda were permitted to carry on experiments with their several processes at the sewage works; the result was that Goodall's process (*i.e.*, treating the sewage with lime, ground coal ashes, nitrate of iron, and carbon, a waste product from the manufacture of prussiate of potash) promised the best effect. The cost of this process for treating the entire volume of the night and day sewage flowing from the works at Knostrop was estimated at 19*s.* per hour, and arrangements were subsequently (in August 1874) made by the corporation with Mr. Goodall to carry on the work for a period of six months; but at the end of that time it was found that the sewage could be clarified on a larger scale at a cheaper rate than it had been done at the smaller works, and it was considered advisable to try the process of the A. B. C. Company at the large works, which were originally built for the A. B. C. process, and from January 1875 to January 15th, 1876, the A. B. C. method was carried out at a cost during this year (for lime, carbon, alum, clay, and carbolic-sulphide, inclusive of labour, fuel, oil, tallow, &c.) of 15,000*l.* This amount is exclusive of the cost of drying the deposit and converting it into a manure, which has not as yet been done.

The corporation have recently (January 1876) arranged with Mr. John Hanson, a manufacturing chemist of Savill Town, near Dewsbury, to treat the sewage by a process for which he has obtained a patent, and he proposes to use, in treating 12,000,000 gallons daily,—

	£	*s.*	*d.*
Six tons of lime at 14*s.* 6*d.* per ton - - - - - -	4	7	0
Seven tons of black-ash at 8*s.* per ton - - - - -	2	16	0
Seven tons of new material (as to which no information was given) at 7*s.* per ton - - - - - - -	2	9	0
	£9	12	0

Or at a rate of 16*s.* per million gallons per day for chemicals alone. To this must be added the cost of labour, coal, and other materials, also the expense of cleaning out the sludge-tanks, and of artificially drying the "sludge" and converting it into a manure. It is estimated that the quantity of suspended and precipitable matters in the Leeds sewage amounts to 40 tons daily, or about 15,000 tons per annum, and not any of this has been sold, which consequently accumulates at the works.

For the purpose of artificially drying the mud and manufacturing a manure therefrom the corporation are erecting two of Borthwick's drying cylinders; these will cost about 4,000*l.*

The Rivers Pollution Commission carefully investigated the A. B. C. process, and in their second Report, 1870, submitted the conclusions regarding it to which their inquiries, observations, and analyses had led them. They say, "As therefore the inevitable conclusion is unfavourable to the A. B. C. process, in respect of its alleged power to hinder the pollution of rivers by town sewage, so also is it altogether unfavourable to the value of the manure which it manufactures. The one statement is, indeed, in some sense the complement of the other, for just in proportion to the largeness of the amount of fertilising matter which escapes must be the comparative worthlessness of the small remainder which is retained."

We collected a sample of the sludge from the A. B. C. process and caused it to be analysed by Dr. A. Voelcker, F.R.S., and the following are the results of the analysis:—

Deposit from the Sewage of Leeds treated by the A. B. C. process.

This deposit in the state in which it was received, and calculated for 15 per cent. of moisture, had the following composition :—

		Calculated with 15 per cent. of moisture.
Moisture	57·20	15·00
*Organic matter	9·45	18·77
Oxide of iron and alumina	8·10	16·09
Tribasic phosphate of lime	0·76	1·51
Carbonate of lime	5·60	11·12
Sulphate of lime	0·45	0·89
Alkaline salts and magnesia	1·40	2·78
Containing—Potash	0·39	0·77
and chloride of sodium	0·02	0·04
Insoluble siliceous matter	17·04	33·84
	100·00	100·00
* Containing nitrogen	0·31	0·61
Equal to ammonia	0·37	0·74

	£	s.	d.
The partially dried deposit containing 57·20 per cent. of moisture contains in 1 ton 17 lbs. of phosphate of lime, worth at 1*d*. per lb.	0	1	5
8¾ lbs. of potash, worth at 2*d*. per lb.	0	1	5½
Nitrogen equal to 8¼ lbs. of ammonia at 8*d*. per lb.	0	5	6
Total estimated money value per ton	£0	8	4½

	£	s.	d.
In a ton of the deposit, with 15 per cent. of moisture, we have—			
34 lbs. of phosphate of lime, worth at 1*d*. per lb.	0	2	10
17¼ lbs. of potash, worth at 2*d*. per lb.	0	2	10½
Nitrogen equal to 16½ lbs. of ammonia at 8*d*. per lb.	0	11	0
Total estimated money value of 1 ton	£0	16	8½

For the true value, see page lxiii.

The cost of treating the sewage in this case is not less than 1,500*l*. per annum for each million gallons per day, and there is no probability of reduction if the present mode is continued. The Committee of Works persist in expecting 1*l*. per ton for the manipulated sludge, which they do not obtain; recently (July 1876) they assert that it is selling at 10*s*. per ton.

In addition to the expense of clarifying the sewage by chemical treatment, there is the cost to the corporation of cleansing the 15,598 privies and middens, removing the refuse (about 80,000 loads) at a cost of 27,000*l*. The expense of cleansing and removing is partly recouped by sale of the refuse, which realizes 9,000*l*., or at a rate of 2*s*. 2½*d*. a load, leaving a deficit of 18,000*l*. The refuse is bought by farmers to be used for manure.

The sewers are ventilated, and, in 1873, 15,000 gullies were converted into ventilators. In the construction of all new sewers ventilating-shafts are built, the gullies are also ventilated, and arrangements are also made for flushing the sewers.

HALIFAX.

Area	(acres) 3,768
Population, about	68,000
Rateable value	£262,581
Inhabited houses	11,218
Waterclosets	2,600
Sewerage works cost	£77,000
Outfall works and tanks cost	£15,954
Estimated volume of sewage every 24 hours (gallons)	2,500,000
Yearly cost of cleaning tanks and removing refuse	£213
Privies on the Goux system	3,159
Yearly cost to corporation of cleansing these receptacles	£1,896
Privies with middens on old system	1,500
Yearly cost to corporation of cleansing these "middens"	£1,100

The borough of Halifax has been sewered; the main sewers are built of stone and brickwork, and the branch sewers are formed of stoneware pipes, the main outfall being into the Hebble at Salter Hebble. The sewers are ventilated by means of side chambers built to each manhole; these are carried up to the surface of the streets and are covered by open grids. The Hebble, a small stream, in its passage through the town is considerably discoloured by refuse from mills and dye works; and, in 1869, it was greatly polluted by sewage. In the month of May of that year, Messrs. J. Holdsworth and Company, whose mill is on the stream about a quarter of a mile from the outfall sewer, filed a bill of complaint in the Court of Chancery, and in July of the same year an injunction was granted to restrain the corporation, from and after the 1st of June, 1870, from causing or permitting the sewage of the borough to flow into the Hebble Brook until the same had been sufficiently purified and deodorised. In February 1870, the late Mr. John Lawson, C. E. (Lawson and Mansergh) at the instance of the corporation, visited Halifax, and after an examination of the district submitted a report on the best mode of disposing of the sewage thereof; he recommended that "an irrigation scheme on a comprehensive scale should be carried "out, and he considered that the 475 acres of land proposed to be pur- "chased by the corporation would probably be sufficient for the "thorough utilization and purification of the sewage of Halifax": he also stated that "tanks or screeners would be required to take out the "suspended matters, and the sewerage could be delivered on to the "greater part of the land by gravitation." The recommendation of Mr. Lawson was not adopted by the corporation, who in the autumn of 1869 called in Mr. J. Bateman, C.E. to advise them, and he recommended that subsidence tanks should be constructed, and that an intercepting sewer of cast-iron pipes, from 18 inches to 30 inches in diameter, should be laid to convey the sewage of Halifax and discharge it into the tanks and thence into the stream at a point below the plaintiff's works; the intercepting sewer and tanks were completed before the 1st of June 1870, and this satisfied the Plaintiffs in the suit. The cost of these works was 15,954*l*. The volume of sewage flowing through the outlet is estimated at 2,500,000 gallons every 24 hours, and in this volume is included about 500,000 gallons of subsoil water. The sewage is not treated by any chemical agent, but flows into the subsidence tanks where the coarser matters and detritus are arrested, but the raw sewage, loaded with the foul matters in solution, passes from the tanks into the Hebble Brook.

In 1871 the Goux Manure and Sanitary Company, Limited, applied to the corporation to be allowed to introduce their dry system into the borough; and offered free of cost to cleanse all the privies which were or would be constructed on the plan they laid down, (*i.e.*) "The ashpits and excrement pits under the privy seats were to be thoroughly cleansed, and filled in with dry rubbish to the level of the floor, and the privy seat was to be made removable so that it could be lifted up to place in, or take away, the 'receiver' or 'tub'; these tubs were to be 30 inches in diameter and 16 inches deep, and in them a certain quantity of absorbent, either of vegetable or animal fibrous matter, was to be placed, a core was to be inserted around which was to be filled in a further quantity of absorbent matters, and the core was then to be removed. The tubs so prepared were to be placed under the privy seat to receive the excreta, and were to be removed and replaced every eight days; the tubs were, when full, to be taken to the depôt, and their contents emptied and mixed together."

The corporation accepted the offer of the company, and the company erected temporary works and plant on land belonging to the corporation at Stone Dam in the borough, but as this land was subsequently required for other purposes, the corporation in March 1873 let to the company land at Salter Hebble, close to the sewage outfall works, at which place the company erected sheds, stables, and offices, for carrying on the process.

About this time the company represented to the corporation that they could not sell the manure manufactured by their process, and that they were losing by the work; and the corporation agreed to pay to the company 7*s.* per annum for every Goux closet cleansed, and if the contract remained in force after the 1st of January 1875, this amount was to be increased to 12*s.* per closet, subject to three months' notice on the part of the corporation, and 12 months' notice on the part of the company. The company gave notice to the corporation in January 1875 to terminate the contract in January 1876, and the corporation are now considering whether they will or not carry on the system.

The company under their contract with the corporation removed about 500 tubs daily from the closets to the works; these tubs were about two thirds full of excreta, and after being emptied of their contents ought to have been thoroughly washed before being prepared for re-use, and although the company professed to have this necessary work done, we saw on the day of our visit to the works, January 16th, 1876, the tubs being lined with the absorbent, and prepared to be used again, without having first been properly cleansed.

The company used at Halifax the refuse shoddy as an absorbent lining for the tubs for which they paid 9*s.* per ton; the contents of the tubs were, when taken to the works, mixed and turned over in a pit, and afterwards thrown into a heap in the store shed. We saw at least 2,000 tons of this feeble manure stored in that shed, the Company not being able to sell it at the price they asked for it, viz., 15*s.* per ton.

For carrying out their system at Halifax the company expended in erecting sheds, buildings, and cottages, and also in making a road to the works, the sum of 2,000*l.*, and a further sum of 500*l.* in providing the necessary horses, waggons, carts, and barrows.

The receipts and expenditure of the company at Halifax for 1875 were as follows :—

RECEIPTS.	£	s.	d.	EXPENSES.	£	s.	d.
Received of the corporation for cleansing 3,159 closets - - -	1,895	0	0	1 manager - -			
Sale of manure - -	700	0	0	1 inspector - -			
Balance (loss) - -	911	0	0	1 foreman - -			
				10 collectors - -			
				8 drivers - -	3,276	0	0
				4 emptiers and packers			
				1 boy - - -			
				Keep of 7 horses -			
				Hire of 8 ditto -			
				400 tons of shoddy -	180	0	0
				Gypsum and charcoal -	50	0	0
	£3,506	0	0		£3,506	0	0

The Rivers Pollution Commissioners, in referring to this process said :—

" It must be remembered, as regards this, and similar expedients, not only that it is but a part of the excrementitious matters which is dealt with, but that even as regards that portion of the excrement which they do remove, they so entirely depend upon efficient cleanly superintendence and direction, that wherever they have merely had the average man to work them, they have failed. Moreover, this very frequent collection of filth by hand from houses, and its removal sometimes through the cottages themselves, almost necessarily under the eye and nose of the household, whatever may be the importance of the economic object aimed at, is universally condemned by our domestic habits as nasty and offensive."

The yearly cost to the corporation of cleansing the old middens, of which there are 1,500, is 1,100*l.* ; the refuse becomes the property of the contractor.

We collected a sample of the manure manufactured by the Goux Company from the store-shed on the works at Halifax, and have caused it to be analysed by Dr. A. Voelcker, F.R.S., and the following are the results :—

MANURE manufactured by the GOUX COMPANY at HALIFAX.

A sample of this manure on analysis gave the following result :—

Moisture - - - - - - -		51·65
*Organic matter - - - - - -		22·70
Oxide of iron and alumina - - - - -		3·96
Tribasic phosphate of lime - - - - -		0·96
Sulphate of lime - - - - - -		0·81
Alkaline salts and magnesia - - - - -		2·37
Containing—potash - - - -	0·30	
and cholride of sodium - - - -	0·38	
Insoluble siliceous matter - - - - -		17·55
		100·00

*Containing—Nitrogen - - - - - - - -	0·67
Equal to ammonia - - - - - - -	0·82

A ton of this manure contains—	s.	d.
21½lbs. of phosphate of lime, worth at 1*d*. per lb. -	1	9½
6¾ lb. of potash „ 2*d*. „ -	1	1½
Nitrogen equal to 18⅓lbs. of ammonia, at 8*d*. per lb. -	12	5½
Total estimated money value per ton - - -	15	4½

For the true value, see page lxiii.

ROCHDALE.

Area - - - - - - -		4,136
Population (about) - - - - -		67,000
Rateable value - - - - - -		£222,000
Inhabited houses - - - - - -		14,288
Waterclosets - - - - - -		350
Cost of sewage, manure, works, and plant - - -		£10,000
Volume of sewage every 24 hours - -	(gallons)	1,250,000
Privies, "middens" - - - - -		2,844
Privies, "pail system" - - - - -		5,462
Yearly cost of cleansing privies on pail system - -		£3,405
Excreta removed yearly - - - -	(tons)	4,224
Manufactured into manure - - - -	(tons)	3,741
Manure sold - - - - - -	(tons)	2,000
Yearly cost of cleansing "middens" - - -		£1,919
Refuse removed - - - - -	(tons)	13,736
Refuse, 5,736 tons, sold for - - - -		£549

Rochdale has adopted the "pail" system for the disposal of the excrements of its 67,000 inhabitants living in 14,388 houses distributed over an area of 4,136 acres, as there were in use on the 28th of January 1876, 5,462 privies on the "pail" system, 2,844 "middens," and only 350 waterclosets, and we were informed that the "middens" are being converted into privies on the "pail" system, at the rate of 20 per week.

The borough has been sewered and these works have been greatly increased since 1853.

In 1853 the corporation obtained an Improvement Act, and the 96th section of that Act provides that it shall not be lawful for the corporation to cause any new sewer to open or drain into the River Roch at any point above the Town Mill Weir, or the stream called the Lord Burn ; but, as the town rapidly extended, new sewers were constructed, and this greatly augmented the volume of sewage flowing into the Roch and seriously polluted it. On the 6th of October 1869 a Bill of Complaint was filed in the Court of Chancery, by Mrs. Sophia Holt (widow), and Messrs. Oliver Holt and William Holt, praying that the corporation be restrained from permitting the new sewers then being laid down in Yorkshire Street or any other new sewer from emptying into the Roch above the Town Mill Weir or into the Lord Burn. On the hearing of the cause, 3rd of January 1870, Vice-Chancellor James granted an injunction as prayed. In order to satisfy the Court, and also with a view of intercepting the sewage and preventing it from polluting the Roch, the corporation, in session 1872, introduced a Bill in Parliament and sought certain powers, one of which was to acquire 1,000 acres of land and on this area to utilize the sewage by irrigation. The land is situate in the township of Unsworth about 5 miles from Rochdale, and is the property of the Right Honourable the Earl of Derby. There was great opposition to the Bill and the clauses relating to the land for irrigation were struck out. The corporation then caused

plans to be prepared of an intercepting sewer to divert the sewage from the Roch, and this work is now being carried out a cost of 20,000*l*. The intercepting sewer commences at Ashbrook Valley on the eastern boundary of the borough, and from that point to Heybrook Valley, it is 4 feet in diameter and laid at a gradient of 1 in 250; from Heybrook Valley to George Street it is increased to 5 feet in diameter; from thence to Duke Street it is further increased to 6 feet in diameter; from thence to the Spodden Valley, it is 6 feet in diameter, but laid at a gradient of 1 in 1,000; and from the Spodden Valley to the outfall into the Roch, below Oaken Rod Weir, it is 9 feet in diameter; laid at a gradient of 1 in 1,000.

When these works are completed there will still be 12 overflow-outlets into the Roch, above the Town Mill Weir, to relieve the main sewers of flood water during heavy storms of rain.

The sewers are ventilated by open grids in the covers of the lamp-holes and manholes; these are placed on the lines of sewers and are not more than 150 feet apart. Owing to the configuration of the town the sewers have steep gradients, and it was found that a considerable volume of sewer gas ascended to the highest points of the system; to remedy this, self-acting valves (as recommended in the published suggestions of the Local Government Board, pages 7, 8, 9,) are placed in each manhole, and this has had a beneficial effect; it has prevented the sewer-gas accumulating at the higher points and has facilitated its escape through the gratings in the surface of the streets.

The volume of sewage entering the Roch, Spodden, Hey-Brook, and Sudden Brook, by the numerous outlets, is about 1,250,000 gallons every 24 hours.

In 1869, the corporation of Rochdale decided that they would not continue the contract for cleansing middens and removal of the contents; and, after some consideration as to the best form of privy and ash place, they adopted the "pail," or that now known as the "Rochdale system."

The corporation have erected buildings as a depôt on a site within the borough, and purchased the necessary plant, horses, and rolling-stock for collecting the excreta and refuse at short intervals. The cost of the works, plant, and stock, up to the 28th of January 1876, has been about 10,000*l*.

The mode of collection is as follows:—"The town is divided into six districts, and each pail-privy is numbered consecutively in a district register, so that in case of any contagious or infectious disease arising in the town, the numbers of the pail-privies in connexion with the houses in which the disease exists can be communicated to the local authority, when arrangements can be made for the daily disinfection of such pail-privies, and for the isolation of such excreta."

"As a rule all pail-privies are empted once a week, to ensure which, the driver of the collecting van, on his return to the works, gives in a list showing the number of each pail-privy from which he has collected; this is posted in a book, in such a form that it can be seen at a glance whether any have been neglected, and on every Monday morning a list of those overlooked (if any) is made, and a supplemental van is then sent out to make good the week's collection; the entire onus of removal rests upon the corporation."

"The pail-privies are supplied at each collection with a fresh pail, which has been well washed, and in which has been placed a liquid deodorizer and disinfectant."

"The collections, according, to the regulations, should be made between the hours of 7 a.m. and 5·30 p.m."

To prevent any nuisance arising from the collecting van when passing through the streets on its return to the works, air-tight lids are placed

upon each pail; the doors of the van also close against india-rubber beads fixed in the rebates, so as to be air-tight.

The ash and refuse-tubs are also emptied systematically, attention being secured to them by the weekly visits which are paid to the privies.

In emptying the tubs the ashes are not thrown on the ground, but are emptied directly into a cart, and before placing the tub again in position the floor of the ash-place is swept.

The process of manufacturing the manure is as follows:—the wet-house refuse is tipped from the carts on to drying floors, and when thoroughly dry is, with the other refuse, passed through a riddling machine worked by steam power, which holds back the paper, vegetable, and other refuse, and separates the cinders in two sizes from the ash; the ash is then removed to any part of the sheds where required, and the cinders are removed and used on the works for generating steam, heating the drying floors, and also for firing the boilers at the public baths; and some of the cinders remain for sale. All refuse, such as scrap-iron, obtained by this riddling is disposed of; the vegetable refuse is burnt, and the ash used in the manure.

The excreta, upon its arrival at the works, is emptied into a trench formed by banks of ash, previously brought into the shed from the riddling machine; when this trench is full a quantity of ash is thrown upon the excreta, and the contents are treated with sulphuric-acid, in the proportion of 24 lbs. of acid to each ton of excreta.

The proportion in weight of the excreta and ashes thus treated are about equal. Trench after trench are formed and filled until the whole floor of the shed is covered. When seven days have elapsed since the formation of the first trench and the ash there used has become sufficiently dry to be again used as an absorbent, new trenches are made in the banks of ash deposited to form the sides of the first trenches, and these are filled with excreta and the ash covered over them and again treated with sulphuric acid, as in the first instance. In this latter case, as ash is only required to cover the excreta, and not to form the banks of the trenches, only 5 cwts. of ash are used to 20 cwts. of excreta. When this second course has covered the area of the shed, the process is repeated in another shed, leaving the first shed at rest for fourteen days, after which it is again treated for a third and also for a fourth time with the like quantity of excreta and ash used in the second course. The total quantities thus treated having become 35 cwts. of ash to 80 cwts. of excreta, the mass is undisturbed for fourteen days, after which it is turned over and remains another seven days, when it is again turned over and for a second time allowed to remain undisturbed for seven days. By this time the mass has become a powdery manure, and is in a condition to be bagged for sale.

In 1875, the cost of collection of the pail-refuse and manufacture of the manure, together with the estimated value of the manure manufactured, was as follows:—

	£		£
Cost of collection - -	3,405	Value of manure manufactured estimated at 1*l*. per ton -	4,420
Cost of manufacture - -	3,651	Loss - - - - -	2,636
	£7,056		£7,056

NOTE.—The Rochdale manure is not readily taken away from the yard at the estimated price of 1*l*. per ton, but gradually accumulates. This is the experience in all cases within our knowledge of this and similar modes of dealing with excreta.

We saw at the works about 7,000 tons of this manure. There is not a ready sale for it. Only 2,000 tons were sold in 1875; the corporation in consequence caused the manufacture to cease. Since April of that year, 1875, the excrements have merely been mixed with house-refuse and ashes, but there is great difficulty in getting rid of the mixture although the corporation undertake to deliver it to the purchaser at 2*s.* 6*d.* per ton, and this appears to be the true value to farmers.

The cost of cleansing the middens and removing the contents is 1,919*l.* per annum, and of the 13,736 tons of refuse removed 8,000 tons are deposited in "tips" within the borough, and for the remaining 5,736 tons the corporation receive the sum of 549*l.* 2*s.* 11*d.*

With reference to the 8,000 tons of "midden" refuse thrown away on "tips," we quote the remarks of the Rivers Pollution Commissioners on the "Collyhurst Tip" at Manchester (see Report Mersey and Ribble Basins, p. 24) "The contents of these ashpits are divided by the scavengers into so-called *dry* and *wet*; and it is a matter of serious importance that it is the latter or obviously filthy part alone which is carried to the manure depôt, the dry rubbish being carried to any place that may be in course of levelling in the outskirts of the town. Of course such a division is most imperfectly made under such circumstances; and it follows that the land is thus filled up with the most objectionable stuff; and as building extends, the surface is gradually covered with houses which, on such foundation, cannot fail to be unwholesome dwelling places. There is now a "tip" in a ravine at Collyhurst, on the north side of Manchester, where land is thus being raised *fifteen* to *twenty* feet over many acres, by the gradual accumulation of filthy rubbish. A sample of water from a pool at the foot of this tip on the outer side of the Queen's Road, which here crosses the ravine, taken a few minutes after rain, so that it represented the drainage water of this bank, and thus fairly indicated the nature of the stuff it had trickled through, and another sample taken at a later date yielded the following results on analysis.

"COMPOSITION OF DRAINAGE WATER FROM COLLYHURST "TIP."

"Results of Analysis expressed in Parts per 100,000.

Dates of collection of samples.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Matters in Suspension.	Organic Matters in Suspension.
June 12, 186 - -	1643·5	32·278	3·631	29·525	0	27·946	331·5	16·88	13·48
July 21, 1869 - -	2310·4	22·591	5·257	15·440	0	17·972	440·0	54·36	26·52

"It will be seen from the above numbers that these liquids contained a very large proportion of highly offensive organic matter. They were, in fact, much richer in putrescible matters than any watercloset sewage we have met with. The whole of the made land, indeed, here smells most offensively and can never be built upon without great risk to the health of those who shall occupy the houses. And this is no exceptional example connected with the midden system. What to do with the fouled ashes, which it accumulates—filthy stuff, too poor for use as manure—is one of the great difficulties of the local authorities almost everywhere in Lancashire."

Results of Analysis of Pail and Ash Manure.

We collected at the depôt a sample of the manure manufactured from the refuse of the "pails," and have caused it to be analysed by Dr. A. Voelcker, F.R.S., and the following are the results :—

This manure is prepared at the Sanitary Manure Works belonging to the corporation of Rochdale, from the contents of pails in which human excreta are collected; these are dried up with finely-sifted coal ashes, and delivered to farmers in a more or less dried condition.

A sample of the Rochdale manure as received contained the following ingredients:—

Moisture		15·13
*Organic matter (including carbonaceous matter from finely sifted cinders)		30·62
Oxide of iron and alumina		17·27
Tribasic phosphate of lime		0·76
Sulphate of lime		4·82
Alkaline salts and magnesia		2·29
Containing potash	0·75	
and chloride of sodium	0·53	
Insoluble siliceous matter		29·11
		100·00

*Containing nitrogen	0·69
Equal to ammonia	0·84

	£	s.	d.
1 ton of the Rochdale manure contains 17 lbs. of phosphate of lime, worth at 1*d.* per lb.	0	1	5
17 lbs. of potash, worth at 2*d.* per lb.	0	2	10
Nitrogen equal to $18\frac{3}{10}$th lbs. of ammonia at 8*d.* per lb.	0	12	$2\frac{1}{2}$
For the true value, see page lxiii.	£0	16	$5\frac{1}{2}$

Mr. Alderman Taylor in a recent return (1876) set forth that a population of 52,000 in Rochdale is supplied with 5,644 pails, from which, in the year 1875 was collected 5,398 tons of excreta. This gives about 9·2 persons, and about 19·1 cwt. of excreta to each tub.

The excreta of one person on an average of an entire population is $2\frac{1}{2}$ lbs. per day, or 8·1 cwts. per year, which, taking 9·2 persons to each tub, gives 74·52 cwts., or 3 tons 14 cwts. per pail; 5,644 pails, at 3 tons 14 cwt. per pail, gives 21,024 tons, as the weight due, if the pails are used by the population to which the statement apportions them, so that about one-fourth of the excreta of the 52,000 persons is alone accounted for. One form of reply may be, that for parts of the day the inhabitants are from home, at work, and use other privies, this, no doubt, is an explanation so far as it goes; the statement however gives no indication of such contingency, neither would such explanation be satisfactory if it had been made; as we see that not more than one-fourth of the excreta is accounted for.

APPENDIX No. IV.

THE LIERNUR PNEUMATIC SYSTEM OF TREATING EXCRETA.

In September 1875 we visited the cities of Leyden and Amsterdam.

LEYDEN.

At Leyden, accompanied by the town clerk (Mr. Kist) and one of the aldermen, we inspected the pumping station and in answer to our inquiries received the following information.

The city of Leyden is built upon about 50 islands formed by the affluents of the Rhine. Here a population of about 39,869 is congregated in about 5,000 houses. Their potable water is derived chiefly from the canals which intersect the city and in some cases at points near the outlets of drains from the houses. These canals are, in fact, not only the main sewers of the city, but the main source of water supply; a large quantity of solid refuse is also discharged into them; this has to be constantly dredged out, and the operation conducted in hot summer weather is very offensive.

The house property drained by the Pneumatic system stands upon an area of about four acres, and consists of a poor-house an orphan-asylum and 146 private houses adjacent thereto, situated at the south of the city in Saint Jakob's Gracht, Koerpoort Gracht, Keifhoet, Gaarmand, Hoef Straadt and Raamsteeg, near to a large canal, and this district is occupied by a population, including 140 inmates of poor-house and asylum, of 1,197, who have in use 156 Pneumatic privies. The entire cost of the works *i.e.*, erecting pumping-station, providing 8-horse power steam engine, air pumps, 5,560 feet of 5-inch cast-iron pipes laid under streets from pumping station to the houses, cocks, valves, and funnels to privies, was 2,833*l.*, or 18*l.* 3*s.* 2¼*d.* per privy, or 2*l.* 7*s.* 6*d.* per head of population. The costs were defrayed by the city council, and we were informed by the town clerk that the council did not propose to extend the system because of the great expense. The engine at the pumping station is only worked for three hours on four days in each week for the purpose of removing the excrements to the pumping station, and the yearly cost of this service, including labour of engine-driver and two turncocks, fuel, and materials was in 1872 333*l.*, or 5*s.* 6¾*d.* per head; in 1873 182*l.*, or 3*s.* 0¼*d.* per head, and in 1874 259*l.*, or 4*s.* 3¾*d.* per head of the population using this service. In May 1875, Mr. M. D. von der Hoef of Oegstgeest near Leyden, entered into an agreement with the Municipal Council to send by his barge, when the canals were open, twenty-five 36-gallon old petroleum barrels twice every week to the pumping station to remove the fœcal matter, and to pay for it at the rate of 2½*d.* per 32 gallons; but, in winter, when the canals are frozen, the municipality are to pay the carriage to his farm, which will amount to 5*d.* per 36-gallon barrel.

We visited the dairy farm of 40 cows belonging to Mr. M. D. von der Hoef and saw the mode he adopted of distributing the fœcal matter over his farm, the greater part of which is in meadow, a fine rich loam on a sandy subsoil; six of the barrels unloaded from the barge were placed on a low wheel dray, and drawn by one horse about a quarter of a mile on to the meadow required to be irrigated; the contents of three of the barrels were emptied into a tank on four wheels, which was then drawn about by a horse from place to place as required, whilst a man with a scoop threw the excrements, which were very dilute, over the meadows. Three men are engaged two days a week in removing the fœcal matter from the city and applying it to the land, and this cost 16*s.* per week, in addition to the sum paid for it. In reply to our further inquiries Mr. van der Hoef said: "I don't know what I shall do with the excreta in

winter (two months) when it is frozen in the barrels. I suppose I must store it in the shed until the frost has gone; I have only had the manure since May 1875, and my experience of its utility is very limited."

AMSTERDAM.

Amsterdam.—In this city we inspected three of the principal blocks of buildings drained by the Liernur pneumatic pipes, and also saw the working of the system. The Director of Public Works (Mr. J. Kalff) and Mr. J. G. van Niftrik, Stads Ingenieur, accompanied us and gave to us the following information.

Amsterdam lies at the influx of the river Amstel into the Y, as this arm of the Zuider Zee, which forms the harbour is called. Canals of various sizes intersect the city in several directions, and divide it into about 90 islands which are connected by means of nearly 300 bridges. It has a population of about 286,932 living in about 30,000 houses. The entire want of spring water at Amsterdam is a serious disadvantage to so large a city. The houses are provided with cisterns for rain-water, which is used by the inhabitants for culinary purposes. The potable water is obtained from a gathering ground situated in the Dunes 13½ miles from the city, impounded in a reservoir which has an area of seven acres, and a mean depth of 20 feet. The city was formerly supplied from a small river, the Vecht, abstracted at a point above Weesp, about nine miles from the city by means of "leggers," or water-barges, constructed for the purpose, and are still used in exceptionally dry seasons.

The whole of the sewage flows into the river and canals, which here, as at Leyden, are the main sewers of the city. The drains for carrying off the fæcal matter and house refuse are mere surface-carriers continued along the edge of the footpaths in the streets; covered over with deal flaps hung to the timber kerbing, and discharging into the river and canals, some of these drains were in a very foul condition.

The Amstel is nine feet in depth, the canals generally three to four feet only, and the thick layer of mud which covers the beds is stirred up by the passing barges Dredging machines are engaged in removing this mud, and this is found to be a nuisance in hot weather. In order to prevent the entire stagnation of the large volume of sewage poured into the river and canals, a supply of clean water is introduced through a sluice into the canals from the Zuider Zee.

The Pneumatic System as described by the Director of Public Works.

The Pneumatic system was, on the date of our visit to Amsterdam, in operation in nine blocks of buildings, partially in the old city and partially in the new town, situated at—

(1, 2). Marnixkade,
(3.) Willemstraat,
(4.) Pieter Cornelisz Hoofstraat,
(5.) Stadhonderskade and Jacob van Campenstraat,
(6.) Bonwkas,
(7.) Focke, Simonszstraat (formerly Looÿersloot,)
(8.) Sarphatistraat and Audueszkade, and
(9.) Heerengracht.

The blocks 1, 2, and 3 are brought in to communication with a central

tank placed between blocks 1 and 2 at the waterside; this tank is distant from the farthest privies in the blocks Nos. 1 and 2 311 metres, and from those in block No. 3, 288 metres. The pipes in block 3 are syphoned under the Lÿnbaausgracht canal.

The length of the pipes in block No. 4 is 725 metres from the extreme point to the canal side, where there is a steamboat.

The greatest length of pipes in block No. 5 is 344 metres; in No. 6, 467 metres; in No. 7, 355 meters; in No. 8, 567 metres, and in block No. 9, 18 metres. The pipes are all of cast iron; and for the blocks 1 and 2 their diameter is 6 inches; the joints are made with caoutchouc rings and tightened with iron collars. In all the other blocks the pipes are five inches in diameter and the joints are made in the ordinary manner with lead.

The depth of the pipes beneath the ground varies from 0·50 to 1·50 metres; the greatest depth is the syphon under the Lÿnbaausgracht canal which is laid at a depth of nearly three metres.

A special form of privy-funnel is connected with the "fall" or soil pipes by syphons; there are about 1,100 of these "privies" in use, by 4,837 persons.

The system was applied in 1871 to blocks 6 and 7, in 1872 to blocks 1 and 2, and to the other blocks in 1873 and 1874.

In block No. 7, the city council not only paid the cost of the works inside the houses, but also the cost of the works in the streets; in the whole of the other blocks, however, they only paid the cost of the works in the streets. The entire cost of the work is therefore not known, but the Director of Public Works informed us that he estimates the cost of the works in the streets at 2*l.* per head of the population, and the cost of the works inside the houses at a like sum, or 4*l.* per head, but the costs of these latter works will greatly depend on the numbers of floors and numbers of privies in each house.

With the exception of the above-named block, No. 7, the work inside has been executed by the owners, and no control has been exercised over the work done; this latter circumstance is much to be regretted, because the good working of a whole system of pipes depends on the proper execution of the works in the several houses. There are consequently places where, from defective house fitting, the system does not work well, so that in some houses the privies do not act as intended.

Supervision of any new work within the houses is now enforced.

Further Statement by the Director of Public Works.

The Director of Public Works in a letter addressed to us, dated 29th September 1875, says:—

"We are afraid that we shall not be able to get rid of the whole production of excreta collected from blocks 1–9; it is evident that this cannot be done when the canals and rivers are frozen over, because the transport, per cart, for great distances cannot pay for refuse stuff of that worth and weight."

"Fixed engines do the work of blocks Nos. 1, 2, 3, and 8, but all the other stations are worked by moveable engines; a steamboat, if the canals are not frozen."

"Many stoppages have occurred in the street-pipes; and in some cases it has been found necessary to disjoint the pipes to remove the obstruction, when it has taken occasionally as much as three days to remedy the defect; stoppages have been caused by towels, rags, chignons, pieces of meat, and solid substances thrown into the privies. Ball-valves are used in blocks 1, 2, 3, 6, and 7; these balls, on becoming fixed, cause very

frequent but less important stoppages. The total quantity of excreta removed weekly is about 75 tons, and two thirds of that quantity is water ; enough to prove that the prescribed rule, not to throw water into the privies, is not observed, but not enough to give ground for the opinion that all the slop water from the houses is thrown in."

"Until September last (1874), the fæcal refuse was leased by a gentleman farmer residing at some distance from the town who paid for each ton delivered at his farm 4*s.*; the delivery of it cost the municipality 3*s.* 2*d.* per ton, and although the lease did not terminate before the end of 1875, the gentleman disengaged himself some months before the expiration of the term. He said the stuff was too dilute."

"The cost of working amounts to at least 5*s.* per head per year, but what we are doing here with our eight different points of working; using steamboat and locomotive, is not a fair trial of the costs of working a good application of the system, as, take a compact block of the town, say 50 or 100 hectares, with a fixed engine in the centre, and the working costs would be reduced."

"Besides these costs of working you have to add the interest on the cost of the plant."

"Though we have not had a very severe winter since the Liernur system has been in operation, I think no other serious difficuly would be met with than the freezing of the diluted fæces in the barrels, which would make it impossible to get the stuff out of them. Captain Liernur pretends that the fæces ought not to freeze, but we know by experience that the diluted fæces do and the Pneumatic system does not produce other than diluted fæcal matter."

"To get rid of the stuff we have sold it, in the spring of this year, for 3*d.* and even for 2*d.* per barrel of 340 lbs. to different customers. This did very well till June or July, when we could not sell any more, the farmers not wanting manure before the end of the first harvest. We hoped to have the same customers in August, if not before, but until now, the end of September, we have had but few of them. They write that they will return in the spring, and we hope and think so, but you see it is a poor bargain to sell only a few months in the year when you are producing the whole year. So that the question of getting rid of the stuff at a fair price wants still a solution."

"Captain Liernur pretends that a former administration has paid no attention to the conducting of the house and kitchen water in separate pipes, and even his friends have insinuated that for that water there was no separate sewer at all, so that people were *obliged* to throw the water into the Pneumatic pipes. Now, this is not the case, where the Pneumatic system is executed at Amsterdam, there is in the streets a separate system of drains for the rain and house water ; in and near each house there are sinks, and in each kitchen there is the kitchen-sink or sewer ; but Captain Lieurnur is so far right that in the blocks Nos. 2 and 3 there are privies *in* the kitchen ; this is an abominable arrangement, and besides is a constant allurement for the cook to throw water into the privy instead of into the sink, the small dimensions of the waste pipe does not afford the servant such a good occasion for emptying her pail at once. However, Captain Liernur goes farther and deems it now necessary that on each floor, in or near the privies there should be a separate sink, the waste-pipe from which should be as large in diameter as the soil-pipe of the privy, so that there should be not the least inducement for the servant to prefer the privy to the sink. Captain Liernur has had occasion to prescribe all these new arrangements, for it is he who projected all the contrivances inside the houses. That

he did not prescribe proper fittings in the first instance is his own fault, and it is a poor excuse for him now to say that this was the mistake of the administration, who had nothing to do with the inside fittings, as they only paid for the works in the streets.

"But what is much more serious and to the point is this, that what Captain Lieurnur proposes now, and what is partly done at Leyden, is to my mind in flagrant disaccordance with the principles of the whole system; there is not the least doubt but that if there were more convenient ways of getting rid of the house and wash water of the upper floors than by the privy, this (the privy) would not be used, as it is now, for the removing of waste house water; but it is not the less evident that the privy, in that case, would *not* receive all the fluid excreta of the night, which would find its way with the wash water down the more convenient sinks. Captain Liernur himself states that perhaps *now and then* the contents of a chamber-pot will be thrown into his privy-pan, as into a sink.

"Now the quantity of the fluid excreta of the night (the blowing off at night and morning before going to sleep and before rising) is estimated at 4/7th part or more of the fluid excreta of the twenty-four hours, and as the fluid excreta does contain seven times as much nitrogenous or putrescible substances as the solid excreta, it results thereby that the making of convenient sinks in or near the privy closets includes the gathering of, about one half of all the excreta in the expensive iron pipes, and the losing, at least the other half of these substances, down the sinks and the earthenware pipes, which are not destined for that use, so that there is the danger of infection, which the whole Liernur system professes to remove.

"In the 'Times' of the 23rd of September 1874, it is estimated that with the Liernur system waterclosets can be used without losing any of the agricultural value of the excreta by dilution. Now this may be the theoretical notion, but practically it is the reverse. Suppose the privy closets combined with the Pneumatic pipes, even arranged as Captain Liernur proposes, so that only a limited quantity of water is thrown in the privy closet each time it is used. He estimates the needed quantity of water at 2 lbs., and I cannot estimate it less; it is known that, on the average, each person uses a closet, or urinal, four times in the twenty-four hours, children do this more frequently. Each time the closet is used, however small the quantity of the excreta may be, 2 lbs. of water is to be thrown into the closet; that is, 8lbs. in the 24 hours. On the average, the production of excreta per head is $2\frac{1}{2}$ lbs. in the twenty-four hours; thereby it results that, even if the contents of the chamber-pot be thrown away elsewhere, the excreta will be diluted with four times their weight of water; that is, you will obtain a ponderous mass of no practical agricultural value; as is proved in Amsterdam, where the diluting with only twice the weight of water suffices to make the manure very difficult to sell at any price, because of the bulk and cost of removal, and in winter of storage. For the same reason, it is not true, what is said in the same paper, the 'Times,' that the system is independent of the house-dwellers, and yet it is stated that these by their inadvertence or mismanagement cause the city much loss by throwing water down the privy, or solids, such as towels and chignons, whereby stoppages occur in the pipes, as is proved by experience. It is said, that the management is in our hands, and that perfect working depends a great deal on the goodwill of the householders and their servants, and a strict observance of given rules, which are in practice grossly neglected. We, however, in Amsterdam dispute this, as we consider that the fault is in the system. We do not think

stoppages can be prevented, neither do I believe that there is a city in the world where the Pneumatic system can yield a good return upon the capital employed. I, however, for my part, don't think this necessary if the hygienic object of the system can be obtained, but I disapprove very strongly of misrepresentation; the system does cost a great deal of money, and therefore must burden the town with taxes.

"In Amsterdam the system is not used by more than some 6,500 inhabitants."

"It is not true that the expense of the Pneumatic system in Amsterdam has only been at a rate of 2*l.* per head of the population, including the changing of the existing privies and all other charges. The 2*l.* per head may suffice for the outside, or street works, if you can use the existing sewers for the rain and house water; but you may reckon at least another 2*l.* per head as the average for the changes inside the houses; or, in the whole, a cost of 4*l.* per head of the population. Of course in new quarters there is no changing; and, therefore less outlay, and the costs of changing in the existing parts of the town differ greatly in various quarters by the construction of the houses, the number of floors, and the number of the house-dwellers. I think, however, that even with a well-arranged system the annual working expenditure for a town of 20,000 inhabitants will exceed 2,000*l.* I know very well that what we are now doing at Amsterdam, though it is done under the advice of Captain Liernur, is not in all respects a fair trial as to the annual expenditure, because the system costs yearly about 1,200*l.* for not quite 5,000 inhabitants; this amount can be lessened much in new works, by not following our example of constructing works in eight different and separated parts of the town, as a compact arrangement would be more economical. However, I think that, basing my opinion on practical experience, it would cost not less than 3,000*l.* a year to carry out the system completely in a town of say 20,000 inhabitants. This would not however signify much if really the promised 10,000*l.* were to be got for the fæcal waste, as stated in the 'Times' newspaper, but we did not get more than 2*d.* for 340 lbs., and the party who had leased the whole for that price abandoned the bargain as soon as he could do so, on the pretence of the excremental matter being too dilute. Now suppose we had sold twice as much water as excreta, then we should have got for the production 1*s.* 6*d.* per head per year, and this for 20,000 inhabitants would be 1,500*l.* a year. If we could realize such an income we should think ourselves very lucky, and we hope the market we are trying to find would continue such an income. The pastures round this town are used principally, if not exclusively, for milch cows, and these meadows don't want such rank manure; but it is not less true, that as long as the canals are not frozen, there is no town situated so advantageously as ours, as, from every point of the city, we can convey, per vessel, this production to other parts of the country.

"I don't think there can be obtained any financial result by the making of poudrette, but we have no experience of that as none has been manufactured here. The city of Dordrecht will, it is said, try it in a few months. It is a great fault of Captain Liernur and his friends to awake high expectations about the returns to be expected from the sale of the manure.

"If there is any worth in the system, it is in the hygienic side of the question, and I think that, in some cases, it may do much to lessen, if not fully to remove, a great existing nuisance. But I don't think it possible to apply the Pneumatic system, for instance, to London."

Badhoeve Farm, Haarlemmermier.

We visited the farm of Mr. J. P. Amersfoordt, at Badhoeve Haarlemmermeer, and that gentleman courteously gave to us the following information:—

"My farm has an area of 450 acres, of which 325 acres are meadow, 75 arable, and 50 timber and plantations; the soil is a rich loam upon a sandy subsoil. I keep a dairy of 45 milch cows, also about 100 oxen and young stock, and about 300 sheep. From January 1873 to December 1874, I received, from Amsterdam, the fæcal matter collected by the Pneumatic system, and the following account gives the quantity delivered each month, and the amount paid for it:—

Months.	Weight in Kilogrammes.	Price paid in Guilders and Cents.
1873.		
May	111,180	300·18
June	154,730	417·71
July	119,420	322·43
August	94,255	254·48
September	146,490	395·52
October	166,615	449·86
November	146,170	394·65
December	198,135	534·96
1874.		
January	215,740	582·49
February	168,100	453·87
March	230,765	623·06
April	224,345	605·73
May	230,285	621·76
June	250,685	676·84
July	305,440	844·68
August	364,130	983·15
September	143,530	I refused to have any more because it was so dilute, and the carriage was excessive, and it was delivered on to the farm during these four months without any charge being made for it.
October	363,275	
November	296,430	
December	91,670	
Total	4,021,390	

Or about 4,022 tons of fæcal matter delivered in 20 months, for which I paid the municipality 905*l.* or at the rate of 4*s.* per ton.

"The excreta was sent to me by barges, and about 100 old petroleum barrels, holding about 36 gallons each, were delivered every day, Sunday included. On arrival at Badhoeve, the barrels were unloaded and carted on to the farm; the contents of five barrels were then emptied into a liquid manure-cart, and drawn over the meadow required to be irrigated; this method of applying the excrements did very well in fine weather, but after rain the surface of the meadows was so soft that it was very difficult to get the cart over the land, even with a smaller load, (*i.e.*, the contents of two barrels at a time.) I found after using the excreta for some time, that the meadows gave little or no indication of being manured, and on my complaining to the municipal authorities of Amsterdam, they caused samples of the fæcal matter to be analysed by Mr. J. W. Gunning, Professor of Chemistry of the University of Amsterdam, and the following are the results:—

"In six samples of excreta, each sample being the mean of a series of samples collected during one week, we detected in each case nitrogen

per cent., No. 1,—0·348; No. 2,—0·366; No. 3,—0·400; No. 4,—0·349; No. 5,—0·336; and No. 6,—0·618, the mean of the six samples being —0·403.

"The municipality had guaranteed that the fæcal matter should contain,—0·9 of nitrogen per cent. After this I declined to take any more of the manure. The barrels contained all kinds of refuse which had been emptied into the privies, such as old rags, shoes, broken utensils, and corks. I should be willing to take the sewage; that is, the whole of the solid and liquid excrements combined, if regularly delivered on to my farm by sewer-pipes, but not in the irregular manner in which it has been delivered. The cost of the fæcal matter and the cost of distributing it over a portion of my farm came to nearly 4*l.* per acre per annum for the land thus manured. Butter being the chief produce of the farm, my milch cows did not graze the meadows which were manured with the excreta, because I knew by experience that it would have given a taste to the butter; and we, in this district, are celebrated for making very fine butter; but oxen, young stock, horses, and sheep fed in these meadows on which the excreta had been put preferred that to any other portion of the pasture.

"The whole of the farm is under-drained to a depth of three feet, the drains are 30 feet apart, and the drain-pipes are so arranged that they can be used for upward, or subsoil irrigation, the water being introduced by means of a syphon laid under the adjoining dam."

Abstract.

These Dutch statements show that the first cost of the pneumatic apparatus is very great, being at a rate of 4*l.* per head of the population, and that the annual expenses are at a rate of 2*s.* per head. This is all in excess of ordinary sewers and drains, and ordinary scavenging. The income, it will be noted, is at present unsettled and uncertain.

The Director of Public Works at Amsterdam, on page 66, states that in his opinion it would cost yearly 3,000*l.* to carry out the Pneumatic system in a town of 20,000 inhabitants, and that the apparatus would cost not less than 4*l.* per head, or a total of 80,000*l.*, which at 6 per cent. is 4,800*l.* per annum, or an annual total of 7,800*l.* If, therefore, London, with its 3,600,000 inhabitants, were to have its excreta removed by this system at a proportionate cost, the annual expenditure would amount to 1,404,000*l.*, and all other main sewerage costs would remain as at present.

PARIS.

The city of Paris has a population of 1,851,792.

Formerly the southern part of the city drained into the Seine and Bièrve; and the northern part into the Seine and Menilmontant; but the whole of the sewage has been intercepted, and now flows to a point at Clichy when it is pumped through iron mains four feet in diameter, carried by the Pont Clichy across the river Seine to Asnières; and thence it flows over a portion of the plain of Gennevilliers. To this land also is conducted, through iron pipes laid beneath the carriageway of Ponts St. Ouen and St. Denis, a considerable volume of sewage from the districts of Montmartre, Belleville, St. Owen, and St. Denis.

The sewerage system of Paris consists of seven principal and fifteen secondary collectors. On the right bank of the Seine there are three principal collectors, converging to a chief one under the Rue Royale ; (which conveys the sewage to Clichy) ; there are also three on the left bank of the river, and these communicate, with the chief one, by means of two syphons under the Seine.

The chief collector is 16 feet in height, 18 feet in breadth, and about three miles in length ; the aggregate length of the main-sewers already completed is about 354 miles.

The Plain of Gennevilliers is well adapted for sewage utilization, as it consists of a light open soil on a gravelly subsoil of considerable depth ; and it, therefore, serves the purpose of a natural filter ; but at the date of our visit, in September 1875, only about 400 acres were under irrigation.

In outline, the Plain very much resembles, although on a larger scale, the sewage meadows of Carlisle bounded by the Eden ; and also the Kendal sewage farm bounded by the Kent.

The principal main sewage-carriers are formed of brickwork, and are 7 feet wide and 3 feet deep, the branch-carriers being 3 feet 6 inches wide and 2 feet deep.

The daily volume of the sewage of Paris is equal to 343,700 tons, but only a limited portion of this (*i.e.*, about 28,000 tons) is used on the land required to be irrigated, the remainder flows into the river Seine at Clichy.

The whole of the solid excrements of the population are not allowed to go into the sewers ; these and the contents of cesspools are collected and removed to the Forest of Bondy, and are there manufactured into poudrette ; but as the streets are cleansed daily and the droppings of horses and surface dirt are swept and flushed through the gullies into the sewers, the sewage contains a large quantity of solid matter, not only in suspension but also in solution.

In 1869 the municipality of Paris, having laid down the carriers, sub-carriers, conduits, and pipes for distributing the sewage over the land at Gennevilliers, conceded to the owners, and also to the lessees of the allotments, the free use of it until 1880, after which time, if they continue to use it, a rent is to be paid. At first there was a great prejudice against the use of sewage as a manure, and also the produce grown by its aid, but this has gradually died out, and the number of allottees who use the sewage increases every year, and the owners and occupiers are much pleased with the result.

The allotments are very numerous, and are let on lease for terms varying from 3 to 15 years.

The crops grown under sewage-irrigation have been a perfect success; they comprised absinthe, artichokes, asparagus, beans, beetroot, cabbage, cordon, carrots, celery, chevil, chicory, cohl-rabi, cucumbers, leeks, melons, onions, parsnips, peppermint, potatoes, pumpkins, spinach, tomatoes, turnips, lucerne, clover, Italian rye-grass, mangolds, wheat, oats, and Indian corn.

The market-garden produce yielded very abundant crops. The asparagus is grown in nursery-beds as plants, and afterwards sold to gardeners, who force it for use of consumers. The Indian corn was of exceedingly luxuriant growth, 9 to 10 feet high. The potatoes gave a very good crop ; the sewage is applied to the land before planting potatoes, and not to the growing crop, except in drought. The Italian rye-grass and lucerne yielded five cuttings for hay and two cuttings green for cattle feeding. It is found that the application of sewage to lucerne more than doubles the weight of the crop. A meadow of natural grass (principally cocksfoot) under sewage treatment, yielded three crops of hay in the year, and these realized 15*l.* 15*s.* per acre. Application of

sewage to young fruit trees has also been very successful. The average yearly rainfall is 20 inches. The hot and dry plain of Gennevilliers is capable of absorbing a very large volume of sewage, especially in the summer season. It is found that the sewage does not readily freeze, and therefore can be applied continuously to the land. The available area of land at Gennevilliers is insufficient to receive the daily volume of the Paris sewage, and we were informed that it is in contemplation to extend the main conduit to St. Germain, and to irrigate the land lying on the edge of the forest, and also the forest itself if necessary.

The effluent water after percolating through the gravelly subsoil flows into the river Seine, and at the date of our visit it was clean, bright, and inodorous.

BERLIN.

The sewage at present flows into large open channels or gutters by the side of the footpaths in the streets; these are principally lined with stone or bricks, and, where they cross the streets, are covered with deals; the gutters are swept by the scavengers daily, and the solid refuse removed therefrom, but the liquid flows from thence into the river Spree and the canals.

A system of sewers is being carried out on the English plan, and for this purpose the city has been divided into five drainage districts, with a separate pumping station to each. The main and branch sewers are built of brickwork, egg-shaped in form; they vary in height from 4 to 7 feet; the subsidiary sewers are formed of stoneware-pipes of of from 9 to 24 inches in diameter. The sewers are chiefly laid at gradients of 1 in 500, the flattest being 1 in 2,400. Each of the five pumping stations will have six engines of 60 horse power each, four "Galloways" boilers, and two locomotive boilers as auxiliaries for getting up steam in emergency. The total pumping power will be 1,800 horse. Each of the pumping stations is estimated to cost 50,000*l*., and the entire cost of the sewerage works, pumping stations, and pumping mains is estimated at 2,000,000*l*. sterling.

No. III. works are nearly completed, and we were informed that the sewerage works in this district would be finished, and pumping at this station commenced in 1876.

The sewers will receive, in addition to the sewage proper, the whole of the rainfall upon the houses and streets; arrangements having been made by which, in heavy storms, more than 4/5ths of the flood-water will escape by specially provided overflows direct into the river. The average yearly rainfall is 22 inches.

The municipal council propose to utilize the sewage in irrigation, and to enable them to do so, they have purchased, at a cost of 400,000*l*. (or about 100*l*. per English acre) 2,000 acres of land, a sandy soil, lying to the north, and 2,000 acres to the south of the city, distant there from about 10 English miles, and these farms are being prepared to receive the sewage.

The sewage will have to be pumped through cast-iron mains, two to each farm, each 3 feet 6 inches in diameter, to a height of 130 feet. It is estimated that the mean daily volume of sewage thus to be dealt with will be 28,000,000 of gallons; of this volume 16,000,000 of gallons will be delivered over the North Farm, and 12,000,000 of gallons over the South Farm; and, from the nature of the soil, it is expected that the whole of the sewage will be absorbed and completely oxidized.

Subsidence-tanks will not be constructed, but the sewage will flow direct from the pumping-main into the carriers, and thence over the land required to be irrigated.

The estimated yearly cost of pumping the sewage is 12,000*l*.

One of the pumping-mains is already laid to the South Farm, and

upon this farm it is proposed to grow Italian rye-grass, roots, tobacco, all kinds of esculent vegetables, but no cereals.

It is also proposed to lay down a branch line of railway from this farm to Marienfelde Station, which is about two miles distant, and by this means to bring the grass and vegetables into Berlin, and, if a ready sale is not found for them, the municipal council propose to keep a dairy of milch cows at their farm, and convey the milk to the city; they also propose to carry on the farms until they are in good working order, and then to let them with the sewage; but they do not propose to sell sewage *en route*, as they expect to make a better bargain by letting the farms and sewage together.

APPENDIX No. V.

EPIDEMIC DISEASE.

Epidemic disease will probably be a means of bringing about the greatest modern improvements in civil and social life, as inquiry and investigation make it more and more apparent that neglect of sanitary requirements in past ages has tended to generate plague and pestilence; and, in modern days, to bring about their occasional revival, with typhoid and cholera added. There are in the cycle of time wholesome and unwholesome seasons, periods of excessive wet, long continued generating malaria, and seasons of parching drought producing famine, the depressing influences in both cases lowering the public health and so exposing the human body to other influences immediately surrounding it which aggravate disease. Wet seasons deteriorate vegetation, and tend to produce disease in animals, so that the food of man becomes unwholesome; dry seasons reduce the produce of vegetation or destroy it altogether, so that man and beast perish. These influences should not be left out of sight in considering causes of disease, neither should they be made too much of; that is, excess of disease should not in all cases be imputed to climate, to seasons, or to the weather, if other causes more potent and deadly can be discovered and which causes can be removed. There are vague notices of great epidemics in remote ages in Ethiopia, Egypt, and India; notices more in detail of the plague in Athens 430 years before Christ; and there are histories of the Middle Age pestilences, plague, sweating-sickness, and black-death, with our modern reports on typhoid-fever and cholera. That which we know of parts of Asia and Europe as to the causes of disease we may infer of India, China, and the other inhabited portions of the surface of the globe; namely, that aggregated populations living amidst filth, devouring unwholesome food, drinking impure water, and living immoral lives, suffer from virulent disease, consequently existence is unwholesome, miserable, and short. Some of the prime causes of disease may be inferred from descriptions of towns, houses, and domestic habits and modes of living during the Middle Ages. Towns were crowded on to the least space possible to afford means for fortifications, the streets were narrow, the houses projecting storey over storey so as to shut out sunlight and diminish the circulation of air, the streets were unsewered and were irregularly paved with large and small boulder stones; if there was a gutter it was down the centre, and over the surface filth from the adjoining houses was scattered and lay there till it rotted. Within the dwelling houses filth also abounded. "The basement floors were mud, over which, in those of the better classes, were spread straw or rushes, and on to which went urine of animals and man, spittle, vomit, sloppings of beer, scraps of meat, bones, refuse from fish, and other filthiness not to be named, which were never thoroughly cleansed, the accumulations going on through long intervals." Such is a brief description of muni-

cipal neglect in England about the time of Henry the VIIIth. A student need not, however, trouble himself to read history to learn how men consented to live amidst filth and neglect of all sanitary precautions in past ages, as in these days of rapid communication he may within the range of Europe visit and inspect towns, dwellings, and populations existing not very much if any below the horrible conditions described by the old historian; but even in Great Britain at this day the description may be accepted as partially true of vast masses of the populations resident not only in the slums of our great cities and towns, but also in our rural villages, the Common Lodging Houses Act and the more recent Artizan and Labourers Dwellings Act having, however, been passed to provide remedies.

In 1848 there was passed the Public Health Act, consolidated into the Public Health Act of 1875, and under this latter Act sanitary work is proceeding. The prime block to more rapid progress being dread of local rating and ignorance of the cost of continued neglect.

As there is no value without human life it follows that healthy human life must be of most value, and consequently that any rates which are necessary to secure health and long life must be worth providing. Past history shows that disease in most horrible forms has from time to time destroyed populations living amidst filth indescribable of their own making. Recent inquiries show that modern diseases of malignant types, such as typhus and cholera, generate out of putrid refuse and gross neglect of sanitary works and operations. Modern civilization aggregates populations, and necessitates modern sanitary improvements, and that form of improvement will be best which permanently produces the most favourable results at the least pecuniary cost.

In cleansing towns, fluid and solid refuse has to be removed; its removal must, therefore, be specially provided for. Rain-water may in some cases flow over the surface by natural channels, and in other cases by channels formed for the surface-water. Towns require to be scavenged, and the solids, ashes and vegetable refuse, have to be removed by carts. Human excreta must also be removed, either in pails or by some other system, wet or dry, or by waterclosets, drains, and sewers. That system which can be established and carried out at the least first cost, and can be worked with the most complete efficiency, will be the best—efficiency implying comfort and wholesomeness. To remove the waste-water from houses and towns as fast as used there must be drains and sewers, as cesspools and water-carts would be impracticable. Through properly constructed drains and sewers water will flow to any required distance, and will wash to the outlet all effete matter from the population at once without any secondary intervention or cost. The sewering of towns and the draining of houses is comparatively new, and there is much imperfect work. There are also numerous mal-arrangements, such as drains and ashpits within house basements, and unventilated waterclosets within the body of the houses and crowded betwixt bed rooms; consequently there are nuisances and fevers, all of which may be prevented. In every form of dry method (there is, however, no such thing as a "dry method") or pail-system, there must be retention, for a time, of the excreta; and there must be fetching, carrying, and returning of the boxes, tubs, pails, or whatever the apparatus may be in which the excreta is received, and the nuisance caused will be in proportion to the time of retention of the excreta within or near the dwelling house, the capacity of the tub or pail to receive the contents without slopping; the regularity, care, and cleanliness in removal; and the treatment of the refuse at the yard or station. If unceasing attention is given to the removal, and rigid cleansing of the tubs and pails at each emptying, and the intervals of removal are short (never to exceed one week), the terrible nuisance of the old privy

and midden system will be abated in some measure; but a week's retention of excreta within or near to dwelling houses must constitute a nuisance. The returns obtained and tabulated in this report show that the cost of tub and pail removal is considerable, and that in no case can the manure be sold to a profit. A rate must, therefore, be levied sufficient to pay the interest on capital and working expenses. The cost of sewering and draining must also be paid for by a rate, but along drains and sewers the excreta will pass without any retention or secondary intervention at once to the outlet, there to be disposed of. Deposition in tanks and chemical treatment of the sewage will remove the suspended solids, but will not produce a pure effluent, neither will the deposited material, sewage-sludge, produce a manure having commercial value. There must, therefore, be a rate in aid to work the best known chemical process as yet tried, or the parties working such processes must lose money. In irrigating land with sewage there is both clarification and purification, in proportion to the strength of the sewage, the volume used over any given area at one time, and the adaptability of the land for the purpose; no mode of treating sewage by deposition and chemicals producing such favourable results. Where sewage can gravitate to land obtainable at its fair agricultural value, there is the least present loss to the community; and, in nearly all cases when the works have been paid for, there will be an available income, a result not attainable by any other known mode of dealing with sewage.

THE PRIVY SYSTEM.

" However perfect in theory the ash-pit privy may be as a means of house scavenging in towns, in practice it has been abominable, and though latterly improved by better organisation and more vigorous superintendence, and the gradual adoption of various ingenious contrivances, it can never be otherwise than highly objectionable—land must get soaked with the drainage water from these cesspools; the air must get fouled with their stinking vapours; the sewers must carry from them to the river that which is most filthy and yet most valuable.

" It was a good suggestion by an opponent of the system, that its friends should picture to themselves the sites of Manchester and Salford, with all their dwelling-houses removed and only the privies left—nearly 60,000 of them—rows, and streets, and crowds of them—scattered about almost as thickly in places as the heaps of manure upon a field that has just received a dressing from the dung cart, each heap, however, no mere deposit by a barrow-load, once a year, but a constant collection and continual soakage of filth, which has for years been polluting every corner to which air or water could have access. Is this the site upon which to build a healthy town? would it not be the first desire of every sensible man to sweep this filth away, to drain and aërate; and, if possible, sweeten this land before a single dwelling-place was built; at any rate, to put a final stop to the process which has accumulated so much dirt, to which, indeed, one may fairly attribute much of the responsibility for the high death-rate disclosed by the returns of the Registrar-General, from the South Lancashire towns. Those returns show that typhoid fever, scarlatina, diarrhœa, and other zymotic diseases, commit fearful ravages amongst the populations exposed to such pestiferous influences.

" The relative polluting effect of sewage from midden towns, as compared with that from watercloset towns, is no mere matter of opinion founded on *à priori* argument. It has been made the subject of direct investigation." (Rivers Pollution Commission Report, Mersey and Ribble Basins, 1870, pp. 28, 29.)

" The proportion of putrescible organic matter in solution in midden

towns is but slightly less than in watercloset towns, whilst the organic matter in suspension is somewhat greater in the former than in the latter. For agricultural purposes, 10 tons of average watercloset sewage may, in round numbers, be taken to be equal to 12 tons of average privy sewage. The average quantity of chlorine in 100,000 parts of watercloset sewage is 10·66, while in midden sewage it is 11·54. This difference is very significant; it shows that, assuming (which is probably approximately the case) all the urine to reach the sewers in both classes of towns, a larger number of individuals contribute to a given volume of sewage in midden than in watercloset towns. Chlorine in these cases represents common salt, and the latter again indicates the proportion of the urine in the sewage. The proportion of chlorine, therefore, ought to give the proportion of average individuals (men, women, and childen) contributing to each kind of sewage, and from this it would follow that the populations producing equal volumes of sewage in midden and watercloset towns are as follows :—

In watercloset towns - - -	1,066
In midden towns - - - -	1,154

The cause of this difference in the volume of sewage per head of population in the two classes of towns is obviously to be sought for in the somewhat increased quantity of water needed by and supplied to the former."*

The Conditions of some Towns, Villages, and Houses in Great Britain at this date, 1876.

1. There are towns, villages, and houses in Great Britain entirely without sewers, house-drains, or even common privies ; the condition of the streets, roads, and lanes, indicating to sight and smell the habits of such populations.—See Health of Towns Reports, 1842, and the Reports of the Superintending Inspectors of the Board of Health 1848, Whitehaven for instance.

2. There are other towns, villages, and houses where there are cesspits, cesspools, and privies, for portions of the population ; the privies and ashpits being in all sorts of improper public places, crowded against houses, with some beneath occupied rooms ; and those in open and exposed places having shattered doors, broken seats, rude ruinous cesspits ; the places and all about them being filthy beyond description.

3. There are other towns and districts situate in porous but waterlogged sites, where there are wells and cesspools side by side ; the subsoil-water, according to the season, rising or falling simultaneously in both wells and cesspools, the water of the wells being dangerously tainted by sewage from the cesspool.

4. There are some towns and districts imperfectly drained by rudely formed stone drains, originally made to remove surface-water, but which the inhabitants now use for sewage ; consequently creating a nuisance.

5. There are towns and districts partially sewered and where waterclosets are partially used, the larger proportion of the population, however, still using common privies and cesspits, whilst many of the inhabitants have no sort of privy accommodation provided, but chamber utensils are used by the females ; the yards, roads, and lanes, being fouled by the males and children.

6. There are towns and districts fully sewered upon correct principles, but the houses are not drained, and, as there is no public water-supply, there are only a few waterclosets—common privies and cesspit-middens remaining.

* Extracted from the First and Second Reports of the Rivers Pollution Commissioners, Mersey and Ribble Basins, pages 24, 25.

7. There are towns and districts which are completely sewered, drained, and have a full water-supply. Cesspools and cesspits having been abolished, waterclosets substituted, and the sewage at the outlet being applied to land for agricultural uses. But even in such towns there are grave defects, as neither sewers nor drains are fully ventilated; and many of the waterclosets are situate in improper parts of the house and are also defectively ventilated.

The defects stated in the above seven cases have been described over and over again in the Sanitary Reports of the last twenty-five years, and there has been, and now is, considerable movement to obviate some of the most glaring evils enumerated. But the local authorities, in many cases, shrink from incurring the first costs of main-sewers, house-drains, the abolition of cesspits and privies, and the establishment of waterworks; the substitution of waterclosets and providing land for sewage irrigation. Hence the adoption of patented schemes of various kinds, dry and wet, for the removal of excreta, all of which are costly failures. The prohibition against polluting streams with sewage has also brought in patented modes of dealing with sewage, the inventors professing to purify it, and to make a portable manure out of the sediment which shall have commercial value. Every such scheme, up to this time, having, however, failed even to purify the sewage, as well as failed to pay working expenses by the sale of any manure made.

Sewering, draining, a public supply of water, and scavenging, are necessary to the comfort and health of town communities, and a purification of the sewage outside of the town is necessary to the health of the country, and so far no form of portable apparatus, wet or dry, dry-earth closet, or Rochdale, pail, can dispense with sewers, drains, and a public water-supply. So far, then, all are agreed. The waste water from houses, streets, yards, and manufactures must flow away through sewers to some common outlet; and, as this fluid is polluted by every form of pollution within a town, though excreta is absolutely excluded, it is, in fact, sewage; it must, therefore, necessarily come under any laws and regulations enacted against polluting streams with sewage. These facts are either not appreciated or are not understood by those persons who adopt the various moveable apparatus and work them at so great a cost to the ratepayers. As to the so-called "dry-systems" there is no such system, because all are necessarily more or less wet. The pails do not receive and remove all the urine, as is shown by the returns of the weights removed by the pails used at Rochdale in proportion to the population. Captain Lienur, in his most complicated and costly pneumatic system, does not profess to remove all the urine, but insists upon special provision being made for the reception and removal of waste-water. As side-by-side with his pneumatic privy-pan-closet, he states that there must be a sink for waste-water and the contents of chamber-utensils entirely distinct from his apparatus. This must also be the case with dry-earth closets, as also with moveable pans, tubs, or pails; either on the Rochdale plan, or indeed on any other such system. These facts being so, where is the advantage gained by all the extra intervention, labour, and costs incurred? The pleas used in favour of these several modes of removing excreta are, their advocates say, greater comfort to the householder, extra cleanliness, freedom from nuisance, and absolute freedom from any form of pollution sufficient to cause disease. This most desirable result unfortunately depends, however, upon so much perfection in the working establishments as to prove, practically, to be unattainable. A dry-earth closet in summer, if not attended to, becomes a small cesspit. And this attention involves daily removal, effective cleansing of the box, and renewal of dry-earth. I have seen dry-earth closets most disgustingly dirty through misuse and neglect. The several portable tubs and pails are also liable to similar contingencies

of neglect, as the tubs and pails are at times left too long on the premises, and they then become over full and slop over and flood the surrounding surface with matter most offensive to sight and smell; the removal of the wet tubs and pails is dirty work, as there is frequently slopping over the street-surfaces from the vans during removal, and some of the stores, depôts, or yards, to which the pails are removed are reported to be very filthy and offensive. The mixing and making into manure is costly and does not pay. The removal of excreta in this manner is encumbered with the removal to and from the houses and the depôt by van and horse, so that for each ton of excreta there is at the least two tons of dead weight to move backwards and forwards with all the labour besides the wear-and-tear involved. In the Liernur system the apparatus draws the excreta to the pumping establishment, but from this point it is loaded into barrels for transmission into the country, where, as we learn, it becomes a nuisance in winter, as the tubs freeze and burst.

With respect to the practical value of any of these concentrated manures, that is concentrated when compared with town sewage, it is difficult to arrive at a reliable estimate, as experience so far tends to prove that the chemist's laboratory estimate of value is not accepted by farmers. The mixed excreta, that is the mixture with ashes, reduces the selling price to 2*s.* 6*d.* per ton, and even at this price there are large accumulations during those portions of the year when farmers are busy with sowing, haymaking, or harvesting. In some towns the mixed manure is given. Whatever may be the demand for portable sewage manure in the future, the several modes of manufacture have so far failed to secure for the patentees any profit. The cost of any really effective mode of dealing with excreta should not be sufficient to condemn it, as means of cleanliness, comfort, and health, are worth paying for; and, if the means used are, under all local conditions, the best for that district, or the ratepayers choose to consider them the best, then they must pay the necessary costs. The promoters of these dry-earth and moevable wet-tub and pail processes are not however contented to perfect and advocate their own special schemes, but they condemn all other modes of dealing with excreta in unmeasured terms,—especially the watercloset,—as this, they say, taints alike the atmosphere both of the town and of the houses. With respect to the use of the watercloset, the case may be thus stated, All parties admit that towns must be sewered, and that houses must be drained to remove surface-water and waste-water from dwelling-houses and factories; this being the case, these sewers and drains must be of cross-sectional dimensions sufficient to remove not less than 30 gallons per day, in dry weather from each inhabitant, and the capacity ought not to be less than five times this to provide for occasional rain. All sewers and drains receive more or less of sediment, washed from roofs, yards, sinks, channels, stables, slaughter-houses, cow-sheds, and manufactories, and along sewers truly formed the entire contents pass day by day to the outlet, and where waterclosets are used the entire excreta, solid and fluid, with the contents from the chamber utensils and slop-pail, pass at once silently and imperceptibly with the sewage to the outlet, there to be dealt with under one set of operations, avoiding every form of secondary intervention involved in a use of dry-earth pan and pail. The entire of the excreta, in proportion to the sewage in dry weather being, by volume, as 1 of excreta to from 100 to 150 of sewage; and in wet weather, the proportion is of course much greater, consequently, in every portable form of dealing with excreta by the dry-earth or tub and pail systems, the bulk and weight is formidable, and the removal costly, whilst in the water drainage system this bulk is unimportant, because it is only fractional. With respect to the supposed nuisance and danger arising from waterclosets, proper construction and

use render any atmospheric or other taint within the house absolutely impossible, and the sewage flowing daily in a fresh state from the closet-pans along fully ventilated sewers gives no injurious taint. There must, however, be no drains nor openings into drains within the houses. Sink-pipes must discharge over or into a drain outside, and waterclosets must be against an external wall, connected with a soil-pipe, which is carried above the roof; the upper end to be fully open, and the watercloset rooms must have a day-light window, and fixed means for permanent ventilation to the external air at the ceiling. With such arrangements, and a good supply of water, one of the best waterclosets will work with perfect safety, and may be, what such places should in all cases be—private. The mode of dealing with the sewage, at the outlet, is in no way complicated nor rendered more difficult to deal with by the addition of the excreta from the watercloset; indeed, if the sewage is used in irrigation, it is dealt with to much better advantage; as the fluid is richer by so much manure. Bedford, Leamington, Croydon, and Cheltenham are cases in point, where the entire populations use waterclosets, and the sewage is also used in irrigation for purposes of agriculture.

That waterclosets can be used on the greatest scale by an entire population, is further proved in the case of London, where, for 3,600,000 population there is, on an average, one watercloset to each 5·5 of the inhabitants, or about 700,000 waterclosets are in use.*

The excreta passed daily from London may be estimated at 4,000 tons, and to remove this in tubs or pails to a distance of five miles, would cost about 1,000*l.* per diem, or 365,000*l.* per annum. The daily volume of sewage and excreta of London weighs about 600,000 tons, and this flows along the drains and sewers to the outlet at no cost but that of pumping, which is about 36,000*l.* per annum. In many towns this cost would not be necessary, as the sewage will flow to the outlet, but in every case of the dry-earth tub or pail systems there must be the cost of hand removal and carting.†

EXAMPLES OF SEWAGE IRRIGATION.

EXTRACTED from the FIRST REPORT of the COMMISSIONERS appointed in 1868 to inquire into the best means of preventing the POLLUTION of RIVERS.—MERSEY and RIBBLE BASINS.

The information extracted from this rivers pollution report bears so intimately on the questions discussed in our Sewage Report, and the several analyses are so full and complete, that we have considered it

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* With respect to waterclosets, soil-pans, and urinals, no watercloset, soil-pan, nor urinal should be supplied with water through a screw-down cock, stool cock, or lever-handle, direct from the water-main, but through a service-box or water-waste preventer.

† The late Dr. Parkes, F.R.S., made exhaustive experiments with disinfectants, and found that it would cost about threepence for the chemicals to disinfect one gallon of putrid excreta, so that the disinfection of 4,000 tons per day of London refuse would cost 11,200*l.*, or at a rate of 4,088,000*l.* per annum, leaving the 600,000 tons of sewage per day (or 219,000,000 tons per annum) untreated. These figures only serve to show the extravagance of disinfectants; as, also, that the small doses of Condy's fluid, or of any other fluid, or solid, passed down sinks, waterclosets, drains, and sewers, can practically have no beneficial effect. Foul drains and sewers can only be disinfected at a cost proportionate to the weight and volume of excreta and sewage in the drains and sewers, and this we see would be enormous; they must be flushed with water. Disinfectants may be used with advantage in hospitals, in sick rooms, and in stables; they may also be used by butchers and by others, but they will be practically useless in cesspools, if only small doses are applied; and it is to this fact attention is intended to be directed. The vestries are only wasting parish rates when they send round carbolic-acid to be poured down street gullies by tablespoonfulls. The foul gullies, drains, and main-sewers, may require cleansing, and if so, should be cleansed by flushing, as a use of chemicals for the purpose will be out of the question, on account of the enormous cost of such applications.

advisable to repeat them, rather than to have incurred the great cost and delay which must have taken place if we had obtained new analyses, which could not in any serious degree have furnished more reliable information than this we have extracted. The questions relative to town-sewage, and the best modes of dealing with it, have been so far exhausted that new experiments are not so much required as condensation of ascertained facts put into the plainest language and the least space. Town-sewage is stronger or it is weaker in proportion to the density of the population, the number of waterclosets in use, and the volume of water with which the excreta is diluted. There are three sources of dilution, as, the volume of water supplied to the inhabitants from waterworks ; the volume of subsoil-water which leaks into the sewers; and the volume of rain or surface-water which is admitted to the drains and sewers during wet seasons. In manufacturing districts there may be both further dilution and pollution if all the fluid refuse is admitted into sewers. This is, however, a question for municipal regulation. The extracts which follow are given to show town-sewage in its crude state and after filtration through land :—

1. *The Sewage Meadows near Edinburgh.*—These have long been quoted as an example of the largest produce known to agriculture, yielding grass of a somewhat coarse and "washy" character, but perfectly well adapted for cow food. These meadows cannot, however, be named as a good example of the agricultural remedy for the nuisance created by town sewage ; for it is poured over them in such enormous quantity that the soil has not fair play given to it as a cleanser, and the water therefore leaves the grass land still filthy and offensive. Even here, however, we have a remarkable illustration of the purifying power of soil and plant. Thus, on April 16th, 1869, when the early crop of grass was being cut, and the meadow land was in full spring growth, three samples of the sewage were taken, No. 1 being of the water in the *Foul Burn*, as it poured, probably 700 tons an hour, over plot No. 11, on the map of the Craigentinny Estate. No. 2 was taken at the foot of this same bed, the water having poured at that rate in half an hour over less than an acre of land. No. 3 was taken at the foot of beds Nos. 45 and 46, the tail water of No. 11, which poured on at their head, having in the meantime taken about an hour to traverse one and a half acres of land. This sample represents the water of the *Foul Burn* as it flowed into the sea. It was not by any means clean, but how much of its filth had been removed during irrigation by the action, for an hour and a half, of two and a half acres of land on many hundred tons of very foul sewage is plain from the following table :—

Raw and Effluent Sewage.—Edinburgh.

Results of Analysis expressed in parts per 100,000.

Date and Number of Sample.	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrites and Nitrates.	Total Combined Nitrogen.	Suspended Matters.		
							Mineral.	Organic.	Total.
No. 1, April 16/69 -	62·20	6·106	3·613	9·510	0	11·445	11·32	28·08	39·40
„ 2, „ „ -	65·50	4·797	2·086	10·579	0	10·798	9·76	16·64	26·40
„ 3, „ „ -	51·60	3·340	·682	1·989	0	2·320	1·28	4·24	5·52
No. 4, April 17/69 -	55·00	5·061	2·842	7·865	0	9·319	28·72	29·88	58·60
5, „ „ -	54·80	4·061	1·988	3·100	0	4·541	5·56	7·40	12·96

On the following day, after a night's rain, when the sewage therefore was more dilute, a sample, No. 4 in the above table, was taken from the *Foul Burn* at Lochend just as it left the pumps, at the rate of about 20 tons an hour, pouring over a plot of Italian ryegrass, 40 yards wide and 44 yards down the slope. It was taking about an hour to traverse this plot of one-third an acre. A second sample, No. 5 in the above table, was taken at the foot of this plot. The composition of these samples is given above; and comparing No. 1 with No. 3, and No. 4 with No. 5, the cleansing agency of the soil, however incomplete, is very apparent. In point of fact, more than three-fourths of the whole filth, soluble and suspended, was taken out of the water of the *Foul Burn* by one hour and a half of irrigation in the first case, and nearly two-thirds of the filth in 20 tons of sewage was taken out of it in the latter case, by irrigation over about one-third part of an acre of the light sandy soil of the Lochend Farm.

The Edinburgh experience, however, is rather one of agricultural profit from the use of sewage than of that perfect abatement of its waste and nuisance, which, in the interest of rivers, we desire to see. This arises from the enormous quantity of the sewer water and the small area of land on which it is used. At Lochend and Craigentinny, on the north and east of Edinburgh, about 230 acres receive the whole drainage of 80,000 people, being at the rate of 350 people per acre. At Grange, on the south side of the city, 16 acres get the drainage of a comparatively small number. At Dalry, on the west, 60 acres or thereabouts receive a very large quantity of filthy sewage, which they are unable perfectly to clean; and there are one or two plots similarly treated on the road to Leith. Here, however, altogether are only 400 acres, whereas the population whose drainage they receive must largely exceed 100,000, and it is not, therefore, surprising that the drainage water leaves the land by no means perfectly cleansed.

The *Foul Burn* which waters the Craigentinny meadows passes first through Lochend farm, where about 20 acres of permanent grass and 8 acres of Italian ryegrass receive as much of it as the tenant chooses to apply. The quantity is, probably, often as much as 10,000 or 15,000 tons per acre during the growing season, besides an indefinite quantity during winter; and, of course, a very small proportion of the filth which it brings down from Edinburgh is deposited here. The stream flows on in almost undiminished foulness to the meadows lower down. In addition to the 20 acres of permanent grass land, there are 12 acres arable at Lochend (of which 8 acres are every year in first and second year's Italian ryegrass) commanded by a self-acting pumping apparatus. A water-wheel, driven by the stream, works a four-fold pump, delivering, when in perfect order, about 1,000 cubic feet per hour, a quantity which, as it works night and day during eight months of the year, corresponds to nearly 20,000 tons, or, even assuming that only half duty is accomplished, is 10,000 tons per acre. In either case it is plain that an enormous quantity is applied—much beyond the needs of the largest possible crop of grass.

The grass of Lochend meadows has averaged, during nine of the spring sales at which it is disposed of by auction, 27*l.* 12*s.* 2*d.* per statute acre. During the past year the highest price attained was 41*l.* 17*s.* 6*d.* per acre; and from that down to 19*l.* an acre has been realised. The Italian ryegrass on the same farm has varied in price from 32*l.* an acre for the first year's cuttings to 25*l.* an acre for the second year's cuttings.

Leaving Lochend the *Foul Burn* pursues its course to the sea on the Portobello side of Leith; but it has for many years been diverted, right and left, to a considerable distance from the original watercourse, and a fan-shaped farm of more than 200 acres, widening out as it gets near the coast, has been thus laid out for irrigation at a cost of about 5,000*l.* This Craigentinny farm includes within its limits land of excellent natural fertility, but it terminates at its lower end in a wide belt of sheer sea sand, which, though now equal in its annual produce to any of the originally superior plots, old men still remember as a barren shore. There is here too a portion of higher land of excellent natural quality watered by a pump, in this instance driven by steam power. The area this year watered thus is eight acres, and as the engine is driven only 300 hours during the six or eight dressings which this land annually receives, the pump, delivering from 60 to 80 tons an hour, does not distribute more than 3,000 tons per acre annually, a quantity which at 1*d.* per ton, if ordinary sewage be taken to be worth so much, many ordinary agricultural crops would easily repay. These eight acres of Italian ryegrass have been sold during the past year at from 25*l.* to 36*l.* an acre,—prices equal to those obtained at Lochend, where four times the quantity of sewage is applied. It would seem therefore, that the enormous surplusage of foul water used at the latter place fails to be of any agricultural service.

In the lower Craigentinny meadows 190 acres receive probably nine-tenths of the *Foul Burn*, and, a night and day waterman being constantly employed in its distribution, it flows constantly over one plot after another; a single dressing of five or six hours being given between the several cuttings of grass to each of the 250 plots, or thereabouts, into which the whole area is divided. The summer's grass of these beds, varying from two to five roods each, is sold by auction to the Leith and Edinburgh cowkeepers every spring, and the maximum value reached last year was 36*l.* 15*s.* per statute acre. The quantity of grass for which such prices are obtained is believed to vary from 50 to 70 tons per acre. And as the means are perfected of distributing the sewage more evenly, and as the subsoil drainage of the land improves, the quantity and price are both increasing year by year. No exhaustion is apparent anywhere. The sewage brings down more than the plants require of every necessary constituent of their food, so that even the poor sea sand is as fertile as the rest, and the land is getting richer year by year, notwithstanding the enormous crops it yields. Taking the average price of the whole 240 acres to be 24*l.* an acre, we have a total annual produce of 5,760*l.* a year extracted by the land and grass from the drainage of 80,000 people, or 1*s.* 5*d.* from each person annually—certainly not $\frac{1}{2}$*d.* a ton over the enormous quantity of sewage which is here applied.

But the area is not sufficient to take up the whole of the filth brought down by the water. A much larger extent of crop could be obtained from the use of it if there were any land convenient on which it could be applied, or if there were a sufficient demand for the produce of it. The Edinburgh experience, therefore, must be quoted not as a successful example of sewage cleansed by irrigation, but rather as an instance of the largest produce raised my means of it from a limited area of land.

2. *Lodge Farm, near Barking.*—We turn now to an example of another kind, where the supply of sewage is limited and where the object has been, from this limited supply, by means of an ample extent of land,

to obtain the largest annual produce. Neither at Edinburgh nor at the farm near Barking in the occupation of the Metropolis Sewage Company has the sanitary result or the purity of the water been the object aimed at. In the latter case, however, it has incidentally been secured. The object having been to obtain by agricultural use the largest return from the sewage used, it became necessary to make it as clean as possible before letting it go. At Lodge Farm, near Barking, the Metropolis Sewage Company in 1866 took about 200 acres, for the most part a light gravelly soil, (an analysis of which is given at page 67,) for the purpose of illustrating thereon the value of North London sewage, of which they hold the concession for a term of years. The land had been accordingly laid out in beds varying from 50 to 150 feet in width, with a central carrier down the middle of each, and having a slope from this carrier on either side, down which the sewage trickles to a midway furrow. The carriers are, as nearly as the general slope of the land allows, horizontal; the slope on either side varying from 1 in 20 to 1 in 60. The sewage is pumped from the outfall on the Thames, near Barking, through a 15-inch pipe to a reservoir on the highest part of the farm, and from that it is conducted in open ditches to the ridge-line carriers of these lands. These carriers, being stopped at intervals by the spade of the waterman, overflow; and the sewage, passing over and through the soil to the furrows, is by them conveyed to the lower slopes of the farm, over which it is distributed until it either sinks altogether into the land, or flows finally off the surface at the foot of the farm. The soil is too pervious and has too hollow and open a subsoil to permit the water to travel far upon the surface, so that after 50 yards at most of surface flow it sinks to reappear only at the mouth of the main drain of the farm; which, nearly dry in ordinary weather, pours a full flow within an hour or two of the sewage being applied to the fields. Samples of water taken here represent therefore properly enough the effect of soil and plant upon the London sewage under such circumstances as the Lodge Farm supplies. The following table gives the composition of successive series of samples taken (1) at the carrier, (2) after 50 or 60 yards of surface flow, (3) after a further surface flow; and (*a*) at the foot of the farm where the main drain pours it into a stream.

Raw and Effluent Sewage.—Lodge Farm, Barking.

Results of Analysis expressed in Parts per 100,000.

Date and Number of Sample.	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Suspended Matters.		
							Mineral.	Organic.	Total.
* 1. April 22, 1868	112·50	12·182	3·664	4·000	0	6·958	—	—	—
* 2. „ „	90·55	4·331	1·872	2·250	·026	3·751	—	—	—
* 3. „ „	91·75	2·768	·624	2·500	·032	2·715	—	—	—
* *a*. „ „	79·25	1·366	·329	·800	2·955	3·943	—	—	—
1. June 23rd, 1869	65·30	2·596	1·715	4·000	0	5·009	18·48	27·80	46·28
2. „ „	74·30	2·028	1·285	2·437	·693	3·985	3·06	3·40	6·46
a. „ „	79·50	·887	·236	·425	2·535	3·121	trace.	trace.	trace.

* In this series of samples the suspended matters were not separated, but the liquids, just as collected, were submitted to analysis.

Comparing 1, 2, 3, with (*a*) in the first, and 1, 2, with (*a*) in the second of these examples, we observe the cleansing effect of land and soil in two separate instances, in both of which about 2,000 tons of sewage passed in the course of nine or ten hours over five or six acres of land ; but in neither of them had the sample received more than an hour's treatment from soil and plant together. The soil of the farm is indeed too hollow and porous to allow the most to be made of the manure. Sinking away even in the channels which carry it from the reservoir, much of the sewage is wasted before it reaches the plant; and the remainder which trickles over the surface of the grass remains there too short a time for the entire extraction of the fertilising matter which it conveys.

It will be seen, however, that the effluent waters marked (*a*) in the two series of trials were to a great extent purified.

Turning now to the produce of the sewage, here considered not as a nuisance but as a valuable manure, it appears that 300,430 tons were, in 1867, used over 56 acres of land, and 2,480 tons of Italian ryegrass were cut off that area. Of the sewage, however, no doubt a great deal was lost in the channels and on the land in first starting the process ; and, as regards the grass, we are informed that a large proportion was killed by the unusual frost of January 1867, only 13 acres, in fact, of the whole extent having been in full bearing; and these yielded 62 tons of grass per acre. It appears, therefore, upon the whole experience, that for every 100 tons of sewage applied one ton of grass per acre was obtained over and above the natural produce of the soil and climate. In 1868 and 1869, experiments over a considerable extent of land have been made with other crops than grass, to which alone, or to equally succulent growths, so dilute a manure as sewage appears at first sight to be adapted. A field of 13 acres of poor gravel that was in wheat in 1867, yielding then about $3\frac{1}{2}$ quarters per acre, was sown in 1868 in the following manner :—$4\frac{3}{4}$ acres with wheat early in November, $2\frac{1}{4}$ acres with winter oats, 4 acres with rye, and 2 acres were planted with cabbages in October, which were taken off in March, and mangold sown in their place. The wheat was twice flooded with sewage, in March and in April, 450 to 500 tons to the acre being applied in the two dressings. The crop produced $5\frac{1}{2}$ quarters, and three loads of straw to the acre. The winter oats were three times flooded in March and in April, over the whole, and over a part in June, receiving in all about 500 tons to the acre. These oats yielded eight quarters of corn, with three loads of straw per acre. The rye was flooded twice, in March and in April, in all with about 450 to 500 tons per acre; it was cut in July, and thrashed in the field, yielding six quarters, with three loads of straw.

If it be urged that in such an unnsually dry season as 1868, good results would necessarily follow irrigation with town sewage, it must be remembered that although these crops no doubt benefited in common with those of the whole country by the lengthened fine weather, the soil is a dry burning gravel, and no sewage was applied to either wheat or rye after the month of April, up to which time there was the ordinary amount of wet weather, without any unusual heat. The same field has been again in wheat and oats and barley, and the experience of 1869, with a cold May and June, equally with that of the hot and dry season of the previous year, bears ample testimony to the power of sewage upon this soil as a manure for corn crops. The wheat has yielded 4 quarters per acre, the winter oats no less than 11 quarters per acre, the barley

ripening unkindly only $4\frac{1}{2}$ quarters per acre; but it must be remembered in all these cases that the field, naturally a poor gravelly soil, was then yielding its third successive grain crop. Most satisfactory results also continued to be reported last year* from Lodge Farm in the cultivation of potatoes, cabbages, beet, mangold-wurtzel, and other green crops. The Lodge Farm experience, confining it to its growth of grass, may be said to represent a return of 5*s*. annually from every individual contributing to the sewage used upon it. Supposing the water supply to be over 30 gallons a head, each person will make 50 tons of sewage annually, corresponding to the production of 10 cwt. of grass, worth 10*s*. a ton.

The experience here, combined with the tabular statement, page , of the analyses of the clear effluent water, pouring from the farm into the neighbouring brook, is sufficiently encouraging for those who are interested in the cleanliness of both town and river.

We turn now to a large number of instances of irrigation, where the object has been not only to make a profit but to abate a nuisance. Such are the cases of Aldershot, Banbury, Bedford, Croydon, Norwood, Rugby, Warwick, and Worthing.

3. *Aldershot Farm.*—The case of Aldershot may be placed first upon the list, because here land has been taken for irrigation, not by the authorities, but by a tenant who, bound no doubt to cleanse the sewage of the camp, yet has for his principal object the extraction of a profit from its use, so that he comes more nearly under the same class with the example last named. Mr. Blackburn here receives the drainage of the North and South Camps, *i.e.*, of a population which is fairly represented by a constant number of 7,000 adults. During winter the drainage of this population, amounting to about 700 tons a day throughout the year, is poured in succession over the several fields of the farm, 80 acres in all, one half being in one and two years old Italian ryegrass, and the other half growing crops of potatoes, mangold-wurtzel, cabbages, &c. During the summer the crops upon the arable half take but little of the drainage of the camp, and it is then poured almost exclusively over the Italian ryegrass land. The soil is the poor sand of the Aldershot waste (consisting of almost pure silica), prepared at considerable expense by levelling and deep grubbing, so as both to provide a uniform slope over which the water may flow evenly, and to remove the ferruginous "pan" which everywhere underlies the soil, and would hinder the even distribution of fertilizing matter downwards. A few deep drains serve to draw off the water which sinks beneath the surface.

The first set of samples A., taken in the afternoon of July 16th, 1869, were, (1) from the reservoir into which the camp drainage flows; (2) from the lower carrier or surface drain of a plot of about an acre in extent, over a width of 50 yards of which it had slowly trickled amidst a growing crop of ryegrass; and (3) from the mouth of a drain the only effluent water from the farm. The sewage was unusually offensive at the time, and the effluent water was apparently clear. The difference of composition indicated by the analyses shows that while the water (1) just poured on had, in its first passage over a surface already richly manured, apparently dissolved and carried with it some of the stuff left by a previous dressing, so that after its 50 yards of passage the sample (2) exhibited in its composition an even larger quantity of filthy matter in solution, yet in the end, and after passing through the land, the organic nitrogen and ammonia as shown in sample (3) had to a large extent disappeared.

* Notes upon the Sewage Cultivation of Lodge Farm, Barking, by the Hon. H. W. Petre.—(Effingham Wilson, Royal Exchange).

RAW AND EFFLUENT SEWAGE.—ALDERSHOT FARM.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

—	Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Nitrogen as Nitrites and Nitrates.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
A. 1. July 16/69	46·6	5·878	2·052	0	9·025	9·484	9·45	6·72	14·28	21·00
A. 2. " "	47·4	7·936	3·053	0	8·267	9·861	9·00	1·76	6·84	8·60
A. 3. " "	18·6	·665	·132	1·152	·486	1·684	3·55	·68	·66	1·34
B. 1. May 1/68	93·40	16·335	2·694	0	13·054	13·444	—	5·30	17·90	23·20
B. 2. " "	39·00	·504	·129	1·312	·622	1·953	—	·38	·02	·40

The set of samples marked B. in the above table were taken on May 1st, 1868. No. 1 was raw sewage, as it passed upon the land, and No. 2 was effluent water from the drain. They indicate an immense reduction in the quantity of all the dissolved polluting materials in sewage by the process of irrigation. The organic carbon was reduced from 16·3 to ·5, and the organic nitrogen from 2·7 to ·1 in 100,000 parts. The above figures show, however, that the whole of this amelioration must not be attributed to the purifying action of the soil and crop, for the solid matters in solution in both series, and the chlorine in series A., point unmistakeably to the admixture of the effluent water with about double its volume of unpolluted spring or subsoil water. All that can be safely inferred from the above analytical results is, that in the series A. the organic impurities, soluble and insoluble, were reduced to less than one-fifth, and in series B. to one-eighteenth, the original sewage in the latter case being much stronger than in the former. Even after this deduction has been made from the observed effect, the result is a very satisfactory one.

In this case the extreme natural poverty of the soil does not seem to have been a hindrance to the efficiency of the process of cleansing by irrigation. The farm, well managed, is covered with a capital plant of vigorous growth, to be fed by the filthy water, which accordingly is greatly purified by the process. Mr. Blackburn lets portions of his land to neighbouring cowkeepers, at 20*l.* an acre; and here the grass, cut in regular rotation, was in the heat of July, when everything was withered and burned up around it, a perfect oasis of luxuriant green, yielding annually its four or five crops of eight to ten tons a piece per acre. The Aldershot farm appears the more satisfactory as an example of the sewage nuisance abated, at the same time that its filthy contents are converted into valuable produce, from the circumstance that a previous attempt to deal with it by subsidence and filtration tanks had been a complete failure.

Supposing 40 acres here to yield 20*l.* an acre, and other 40 acres to owe one-half of their crops, or 10*l.* an acre, to the winter sewaging, we have here a return of 1,200*l.* from the waste of 7,000 adults, or 3*s.* 4*d.* per head per annum.

4. *Carlisle.*—The sewage of Carlisle finds its way, for the most part, into the *Eden* through the main sewer beneath the alluvial pasture land bordering the river. It is delivered in the middle of the river channel through a submerged iron pipe. On the town side of the meadow a pumping station has been erected by Mr. McDougal, to whom the land (about 100 acres) is let; and a quantity is thus

lifted, deodorized by treatment with carbolic acid, and distributed over the land by means of light portable iron troughs. These are shifted from place to place by the man in charge, and in this way the sewage pours on at one place after another, distributing itself with more or less regularity, according to the natural surface of the land, which has not been levelled,—flowing here, ponding there, soaking everywhere. There is an obvious increase in this way to the natural fertility of the land; and a larger quantity of stock is kept upon it than it would naturally maintain. There is no surface drainage from the land to the river, and our sample for analysis was taken by digging a hole three feet deep, close to where the sewage had been lying on the previous day, and taking the water to which we at length came.

RAW AND PURIFIED SEWAGE.—CARLISLE.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	mmonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
Raw sewage, Sept. 23, 1868.	44·9	2·673	·505	1·912	0	2·080	—	5·24	4·64	9·88
Water from hole dug in irrigated meadow, Sept. 23, 1868.	28·8	·591	·204	·025	0	·225	3·18	0	0	0

As there is properly speaking no effluent water from this meadow, the whole of the sewage applied being absorbed by the sandy soil and there being no drain outlet, the result is not quite so trustworthy as in other cases; nevertheless we may fairly conclude from it that the soakage from the irrigated land into the neighbouring river is effectually purified.

5. *Penrith.*—Here the drainage of a town of 8,000 people, only partly provided with waterclosets, is received on 80 acres of good meadow land near the *Eamont.* A little more has been done here than at Carlisle to distribute the water by means of permanent carriers; but the treatment is otherwise the same, and the result is very similar. A very large stock of cattle and sheep is kept upon the land to graze down the abundant growth of grass which is obtained.

RAW AND EFFLUENT SEWAGE.—PENRITH.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
Raw sewage, Sept. 24, 1868.	53·5	5·111	1·899	10·395	0	10·460	—	5·88	11·88	17·76
Effluent water from drain as it enters the Eamont, Sept. 24, 1868.	21·9	·320	·108	·001	0	·169	2·68	0	0	0

Here, as at Carlisle, the whole of the sewage is absorbed into a porous sandy soil, but the drain passing beneath the irrigated land, and alluded to in the table, pours out a considerable and clear stream into the *Eamont*, and from this the sample of effluent water whose analysis is given was taken. The comparatively small proportions of solid matters in solution, and especially of chlorine in the effluent water, point to the admixture of unpolluted subsoil water with the true effluent sewage, and the figures in the above table indicate that no less than three volumes of this pure subsoil water mingled with one volume of the real effluent sewage. But even after making this deduction from the purifying effect of the irrigation the result is still satisfactory. The whole of the suspended impurity was removed whilst a reduction of the organic matter in solution was effected to the extent of 75 per cent. of organic carbon and 77·2 per cent. of organic nitrogen.

6. *Rugby.*—At Rugby, a town of more than 8,000 inhabitants, the Board of Health have taken a lease of 65 acres of land for a term of 31 years, at a rental which, with rates and taxes, amounts to 4*l.* 10*s.* per acre ; and, confident in the powers of their somewhat gravelly soil (lying upon a clay subsoil) to cleanse their town drainage, and to convert it into valuable produce, they have laid out nearly 5,000*l.* on the works required for the distribution of the sewage water over it. An intercepting sewer takes the drainage of all the upper part of the town by natural gravitation to the top of the farm ; and, by a deep and costly tunnel drain, the waste of all the lower part of the town is made to flow (along with the tail water of the upper fields) over about 16 acres of the lower part of the farm.

The quantity of sewage at command is about 900 tons a day, or nearly 4,000 tons per annum for every acre of the farm. The land has been in hand for only one year, and much of it was sown with Italian ryegrass for the first time in the spring of 1869, so that the best results can hardly have been yet realized. The third and fourth cuttings (both heavy crops) were, however, ready in the following month of July, and a sale was being obtained for the grass at 8*s.* a ton upon the land. A considerable portion had been let at 10*l.* an acre ; and the 16 acres at the lower end of the farm had supported throughout the spring and summer 54 head of cattle, consuming at least four tons of its grass produce daily ; and a considerable extent of the crop on these 16 acres had been made into hay. In illustration of the cleansing power of land and plant at Rugby, three samples taken about mid-day, July 13, have been analysed ; No. 1 was raw sewage taken from the hydrant as it poured over the top of the farm ; No. 2 was the same sewage taken at the foot of 1½ acre of land in Italian ryegrass over which it had passed 150 yards down the slope. Thence it flowed along a surface channel about 300 yards to another acre of Italian ryegrass ; and No. 3 was taken at the foot of this grass plot about 80 yards from the carrier which supplied it. The following table gives the results :—

Raw and Effluent Sewage.—Rugby.

Results of Analysis expressed in Parts per 100,000.

Rugby Samples.	Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Nitrogen in Nitrites and Nitrates.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral	Organic.	Total.
1. July 13/69 -	52·60	5·505	2·322	·000	7·276	8·314	8·25	3·48	8·96	12·44
2. " " -	55·70	2·547	·506	·000	2·772	2·789	10·20	·72	·28	1·00
3. " " -	68·20	1·526	·164	·000	·420	·510	10·50	·88	·36	1·24

Here then is a case in which the nuisance of the sewage is entirely abated, and so much produce realized as to make it probable that the remedy, which has been here an expensive one, will yet prove profitable,

The following account of the experience of 1869 at this place has been communicated to us by Mr. T. M. Wratislaw, Clerk of the Local Board of Health :—

"The gross produce of the sewage-farm, for the year ending 31st December, has been 544*l.* 16*s.* 8*d.* The total expenses, so far as the payments (including wages for the year) have been made, stand at 458*l.* 8*s.* 5*d.*, and I do not apprehend much addition."

"I am not aware of the actual number of persons contributing to the sewage utilized, but should estimate 7,800."

7. *Banbury.*—A population of about 11,000 people here drain into tanks, from which, through a 12-inch pipe, the sewage is driven by steam power a mile or more to the upper end of a farm of 136 acres, a lease of which has been taken for 21 years, at a rent of 4*l.* 10*s.* per acre. The quantity thus applied amounts to about 300,000 gallons a day, or about 4,000 tons per acre per annum over that part of the farm which is under irrigation. The sewage settles to some extent in the tanks from which the pumps lift it, and both mud and scum are here taken from it, and mixed with the street sweepings and other scavenging refuse of the town ; and 2,000 tons of this compost were sold last year, for which a sum of about 100*l.* was received at the depôt, the material being loaded by the purchaser into barges on the canal close by. The liquid part, delivered on the highest part of the farm, having about 17 feet of fall before it reaches the river *Cherwell*, flows twice or thrice over successive fields before it is finally dismissed, and the extreme filthiness of the river formerly complained of is now satisfactorily abated.

The following samples illustrate the cleansing process which the sewage thus undergoes. The series A. was taken at our visit to Banbury on October 17th, 1868; No. 1 being the sewage which had accumulated in the pumping well from 10 a.m. to 2 p.m., and No. 2 the effluent water as it left the meadows at 1 p.m. The series B. was collected on July 14th, 1869. No. 1 was taken at 10 a.m. and at noon, being raw sewage taken partly from the upper carrier on the farm and partly from the pump well. No. 2 was the water after it had passed over 200 yards in length, and four acres in extent of a field of Italian rye-grass, at the rate of, probably, 70 tons an hour. No. 3 was taken after this tail water had travelled half a mile in an open carrier, and then distributed itself over a flat meadow of permanent grass land. It was passing from the underground drain of the field in question, and represents the sewage as it reached the river. The farm is for the most part a very stiff soil, and the greater part of it is still in old grass land, and neither circumstance is favourable to its efficiency; the former because the soil tends to crack in dry weather, thus given the sewage direct access to underground drains, and thence to the river before it has been properly acted upon by the soil ; and the latter because the surface of the land not being specially and evenly laid out for irrigation, the water tends to collect in shallow ponds or puddles, to the injury of the produce, without being itself materially cleansed. The accounts given of the produce of the land are satisfactory, and it is believed that the farm will soon repay rent, and costs, and loan, so that the nuisance hitherto created by the town will be ultimately abated without any serious permanent charge upon the inhabitants.

The produce of Italian ryegrass and of the meadow land is sold by auction as the successive cuttings are ready for the scythe; and prices varying from 3*l.* to 5*l.* an acre have been obtained per cutting. The following are the results of our analyses:—

Raw and Effluent Sewage.—Banbury.

Results of Analysis expressed in Parts per 100,000.

Banbury Samples.	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Nitrogen in Nitrites and Nitrates.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
A. 1. Oct. 17/68 -	111·5	6·246	2·764	·000	13·590	13·956	—	3·90	8·62	12·52
A. 2. „ „ -	70·9	2·241	·549	·000	2·282	2·428	13·25	·52	·84	1·36
B. 1. July 14/69 -	92·4	8·269	2·386	·000	6·702	7·905	8·75	9·56	20·12	29·68
B. 2. „ „ -	66·5	2·670	1·127	·000	3·112	3·690	6·75	1·68	3·84	5·52
B. 3. „ „ -	51·8	1·008	·207	·668	·725	1·472	5·50	·94	·80	1·74

The Banbury sewage, owing to a deficient water supply, is sometimes much above the average strength, and consequently its efficient cleansing is then a more difficult operation; nevertheless the above results are by no means unsatisfactory; and they are improving, both as regards the cleanness of the effluent water and the returns from the use of it.

The following account of receipts and expenses, in respect of the sewage-farm here, for the year ending Lady-day 1869, has been supplied to us by Mr. T. Pain, the town clerk:—

Receipts.

	£	s.	d.
Amount realised from sale of ryegrass - - -	561	16	6
„ „ mowing grass - - -	347	18	2
„ „ oats - - - -	198	0	0
„ „ aftermath - - -	166	11	8
Right of shooting over farm, and sundries - -	6	1	6
	1,280	7	10

Payments.

	£	s.	d.	£	s.	d.
Mr. Tomline, a year's rent less property tax	605	3	1			
Rates and taxes for the year - -	57	4	7			
Coals for engine - - - -	111	16	0			
Labour expended in cultivation of farm -	216	2	0			
Seeds, implements, &c. - - -	82	0	6			
Manager's salary - - - -	45	0	0			
Auctioneer's expenses of sale, including commission - - - - - -	73	6	11			
				1,190	13	1
Profit on farm - - -				89	14	9
Instalment of principal and interest in respect of loan of 4,000*l.* borrowed to carry out the irrigation work -				250	0	0

The produce of the summer of 1869, when we were over the farm, bid fair to at least maintain the satisfactory character of the account on the previous page.

8. *Warwick*, a town of 11,000 inhabitants, occupying 2,400 houses, of which upwards of 2,000 are connected with the sewers, has lately poured its sewage over a clay-land farm of 100 acres, about a mile away. The quantity thus pumped, and which formerly fouled the *Avon*, amounts to about 600,000 gallons a day, double the water supply of the town, or nearly 1,000,000 tons a year, corresponding to 10,000 tons per acre annually. A large quantity of very dilute drainage water thus flows over a very stiff and therefore less appropriate soil. What the result is, as regards its cleansing powers, appears from the following analyses:—No. 1 is a sample of raw sewage taken from the receiving tank by the pump at 4 p.m. on July 14th, 1869. No. 2 is the sewage after flowing over seven acres of recently-cut Italian ryegrass taken at the foot of a field of red clay soil down which it had flowed probably 200 yards at the rate of 80 or 100 tons an hour. No. 3 is the same water after a second cleansing over three acres of Italian ryegrass in a field of similar soil. The results here may be taken to represent the powers of plant growth and of mere surface action of clay soil, for none of the water apparently had sunk into the land or been absorbed. Here the filth in about 150 tons of dilute sewage had been satisfactorily reduced by probably two hours' irrigation treatment, under what must be pronounced unfavourable circumstances. Moreover the sewage, and consequently the residual impurities had obviously undergone concentration by evaporation, as is seen from the continuous increase of chlorine in the successive samples.

Raw and Effluent Sewage.—Warwick.

Results of Analysis expressed in Parts per 100,000.

—	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Nitrogen as Nitrites and Nitrates.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
1. July 14/69 - -	66·90	5·133	1·680	·000	2·439	3·689	6·30	2·64	3·36	6·00
2. „ - -	69·70	2·727	·575	·000	1·705	1·979	7·70	3·30	·78	4·08
3. „ - -	66·10	1·454	·175	·137	·839	1·003	8·15	Trace.	Trace.	Trace.

The farm has been in hand for two years. Pumping commenced only in the autumn of 1868, and it was not continously carried on until the following year. This, together with the difficulty which the low and flat part of the farm presents to the proper drainage from it of so large a quantity of water, has hitherto delayed the satisfactory financial result which is looked for. Nevertheless the nuisance is sufficiently abated, and large crops of Italian ryegrass have been obtained, for which a ready sale at 10*s.* and 12*s.* a ton upon the ground has latterly been obtained. The farm must, we understand, pay at least 1,600*l.* a a year to replace the costs which the town has already incurred and still bears in respect of rent, pumping, and works.

9. *Worthing*, containing about 8,000 inhabitants, has hitherto fouled a stream running into the sea two miles to the eastward of it. The town drainage now runs to a tank from which it may flow as heretofore, and still does run during the night, so that a good deal of very offensive filth even now lodges in the bed of the stream. During the day it is pumped and flows upon the land of the Worthing Land Improvement Company, who have about 100 acres on which to receive it. The soil is a good free loam perfectly well adapted for their purpose, and the natural slopes are quite sufficient for the easy distribution of the water. There are on the lower part of the farm upwards of 40 acres of an alluvial flat of natural grass on which the effluent drainage of the higher arable land received before it leaves the farm. Mr. W. Hugh Dennett, solicitor to the Worthing Land Improvement Company, has communicated to us the following account of the gross receipts and working expenses of the sewage-farm for the year 1869 :—

	£	*s.*	*d.*
" Receipts - - -	1,807	4	9
" Expenses - -	1,045	6	9
" Balance - -	761	18	0

" In the above expenditure is included a sum of 51*l.* 13*s.* 11*d.* for a 'Level' rate, made for the protection of various lands from the encroachments of the sea, which is a special and not an ordinary parochial rate. There is also included a sum of 50*l.* for the rent of 8½ acres of the land referred to and comprised in the area stated below. A steam engine on the farm was used for about three months at a cost of about 25*l.*

" The population of Worthing is about 7,600.

" The engineer reports that the average volume of sewage pumped each day of 24 hours to the farm is about 480,000 gallons (of which about 130,000 gallons are spring or surface water). In addition to this, about 80,000 gallons of water per day flow into the *Treville* stream.

" The extent over which the sewage flows is about 83 acres.

" The whole farm consists of about 96 acres, a portion of which is not sewaged ; 42 acres are pasture land.

" I cannot say that the pollution has altogether ceased, because although it is stated that the 80,000 gallons of sewage flowing into the stream per day is top water, yet it flows from the sewage-well, and must be necessarily polluted with sewage. However, the actual pumping of the sewage into the stream ceased some months ago, and the communication has been removed. The Local Board of Health have also cleansed the stream, and there is reason to believe that all the sewage pumped goes upon the land, though materially diluted by spring and surface water."

Our samples of the Worthing sewage were taken on July 15th, 1869, about 3 p.m., (1) from the head carrier, (2) from a carrier 150 yards lower down at the foot of a field of Italian ryegrass, over three or four acres of which the sewage was passing at about the rate of 60 tons an hour, and (3) from the effluent stream at the foot of the farm after it had further spread over two or three acres of the flat alluvial grass plot by the river. The following results were obtained on alalysis :—

Raw and Effluent Sewage.—Worthing.

Results of Analysis expressed in Parts per 100,000.

—	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Nitrogen in Nitrites and Nitrates.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
1. July 15/69 -	57·6	2·312	2·021	·000	3·717	5·082	10·75	1·86	4·74	6·60
2. " " -	58·8	1·164	·226	1·105	·801	1·991	11·40	Trace.	Trace.	Trace.
3. " " -	59·8	1·324	·334	·248	·591	1·069	11·00	"	"	"

The sewage, which was somewhat weak at the time of our visit, was sufficiently cleansed by passing over the first plot; indeed it was cleaner than another sample from the effluent stream which was probably carrying into the river the purified water from the stronger morning sewage. Close proximity to the sea affects the proportion of common salt in the Worthing sewage. The proportion of chlorine in all the samples is much higher than the strength of the sewage would lead us to anticipate. Some of the streets are watered with sea water.

10. *Bedford.*—At Bedford, which contains about 15,000 inhabitants, large sums have been recently laid out under the direction of Mr. John Lawson, C.E., on both its water supply and its drainage system. The sewers here receive not only the fouled water-supply of the town, together with a certain proportion of the rainfall on its houses and yards, but an immense quantity of land-water from the gravel site on which the town is built. Thus, though the water-supply does not much exceed 150,000 gallons daily, the quantity of drainage which reaches the pumping station, about a mile below the town, is as much as 500,000 or 600,000 gallons daily. Each of the two 12-horse power engines here stationed is, however, capable of lifting 2,000 gallons a minute to a height of 20 feet, so that either of them can master the ordinary dry-weather sewage of the place.

During the night the comparatively pure water which then drains away is stored in the outfall sewer and tank at the pumping station. In the daytime it is delivered by an 18-inch iron pipe to the irrigated land 400 or 500 yards off, flowing thence into a small circular tank, and afterwards by two 15-inch pipes, along either side of the nearly flat land which has been laid out in transverse beds for its reception. These beds are about 70 feet wide on the side, with a fall of 8 or 10 inches from the central carrier to the midway furrow. The carriers are either 5-inch pipe tiles with open longitudinal slit, or 8-inch half round tiles; and a fall of about 1 in from 300 to 800 is given to them.

The beds were sown in 1868 with Italian ryegrass, and have yielded heavy crops. Up to the middle of July three crops had been cut off 20 acres, besides one crop off 15 acres sown in 1869, and the sales amounted to nearly 330*l.* A much larger area of land is about to be taken in hand for irrigation purposes by the Corporation. The extent at present rented is about 50 acres, but a farm of about 200 acres will ultimately be under their management. The cost of pumping, which amounts to 4*l.* per acre of the land now irrigated, will then be reduced

to a rentcharge of about 20*s*. an acre, which will be more easily repaid. And as the houses become more generally connected with the sewers, both the need of the greater area, and the produce derived from so large a supply of fertilizing matter, will increase. At present, as the following analyses show, the sewage is very weak, but the cleansing process is satisfactory. The samples of raw sewage (1, in the following table) were taken from the above-mentioned tank upon the farm; the effluent water (2) was taken from a ditch, which is dry except when the sewage is pouring on the land, but which was then flowing rapidly, being supplied from the subsoil drainage of the field which was being irrigated.

Samples were taken by us on three occasions. Series A. was collected on Sept. 10th, 1868, series B. on Oct. 10th, 1868, and series C. on July 24th, 1869.

Raw and Effluent Sewage.—Bedford.

Results of Analysis expressed in Parts per 100,000.

Times of Collection.	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Nitrogen in Nitrites and Nitrates.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
A. 1., 4.45 P.M.	74·8	2·732	·668	·000	2·700	2·891	—	13·26	13·14	26·40
A. 2., 5.0 „	76·8	·575	·163	·398	·023	·580	7·15	0	0	0
B. 1., 12.30 P.M.	79·4	1·877	1·304	·000	4·300	4·845	—	5·58	5·50	11·08
B. 2., 1.30 „	78·3	·742	·381	·600	·010	·989	7·25	0	0	0
C. 1., 4.50 P.M.	76·1	2·256	1·301	·000	3·100	3·854	10·90	8·16	13·68	21·84
C. 2., 5.30 „	81·7	·558	·034	·505	·095	·617	8·17	0	0	0

The undertaking here is thus shown to be sufficient as a sanitary agency, and its ultimate profitableness appears probable from the character of the crops we saw growing on the land. The Italian rye-grass must have weighed 12 to 14 tons per acre. The mangold-wurtzel and kohl-rabi were tolerably promising. The prices obtained by auction for the former crop were improving at the successive sales, as the prejudice against sewage-grown cattle food was dying out. The difficulties connected with the even distribution of the liquid will also diminish every year as the settlement of the moved land enables the necessary corrections of the surface to be made, so as to ensure a more uniform flow of water over it. The following report for 1869 has been furnished by Mr. John Lawson, C.E.:—

"The land leased by the Corporation from the Duke of Bedford contains 54a. 3r. 7p. Of this area 47 acres have been irrigated by sewage.

"Two fields, containing about 22 acres, were sown with Italian rye-grass in 1868, and the produce sold from this land in the year 1869 was about 420*l*.

Of the remaining portion of the land irrigated 15a. 2r. were sown with Italian ryegrass in the spring of 1869, and the remainder with mangold-wurtzel and other root crops. The sales from this portion amount to about 227*l*. 10*s*. 4*d*., making a total of 647*l*. 10*s*. 4*d*.

				£	s.	d.
"Produce in the year 1869 as sold by auction -				647	10	4
	£	s.	d.			
Rent, 55 acres at 4*l.* 10*s.* - -	247	10	0			
Auctioneers commission - -	33	8	6			
Printing - - - -	22	9	0			
Seeds and plants - - -	33	19	0			
Labour, including salary of manager	213	4	0			
Taxes - - - -	17	14	8			
Sundry expenses - - -	11	19	0			
				580	4	2
				£67	6	2"

11. *Norwood.* The history of the facts connected with sewage irrigation at Norwood and at Croydon has been sufficiently prolonged to make it now thoroughly trustworthy and instructive. At the former place about 30 acres of low-lying clay land, with sufficient slope for natural surface drainage, have been well laid out for irrigation by Mr. Baldwin Latham, C.E. The drainage of about 4,000 people is received into a subsidence tank at the upper end, and thence flows along surface carriers, arranged both nearly in contour and down the slope. The fall in these carriers varies from 1 in 100 to 1 in 1,000, and the water stopped at intervals in their course flows over their edges, and so finds its way over the surface of the land. Plots varying in size from one to three acres are irrigated at once, according to the abundance of the supply, which, especially in summer time, when it is most wanted, is barely sufficient for the proper irrigation of the land. Nevertheless, very good crops of Italian ryegrass are cut five or six times a year; and a ready sale is obtained for the produce, at prices varying from 9*d.* to 1*s.* 3*d.* per rod, or 6*l.* to 10*l.* per acre, and the Croydon Board of Health have in this way obtained a revenue of 22*l.* per acre during nine months of 1868, and 25*l.* per acre in 1869, which spread over the population to whose drainage it is due, amounts to about 3*s.* 9*d.* per head per annum. Mr. Baldwin Latham has furnished the following satisfactory report of the past year's experience :—

				£	s.	d.
"The total amount received for the produce in the year was - - - - - -				741	0	6
The expenditure has been as follows :—						
	£	s.	d.			
Rent after deducting income tax -	292	16	3			
Wages for cutting produce, attending to the distribution of the sewage, re-digging and otherwise preparing the land for crops -	196	1	3			
Seed - - - -	17	2	6			
Taxes, rates, and tithes - -	63	15	3			
Printing - - - -	2	3	0			
Sundry bills - - -	20	16	6			
				592	14	9
Balance - -				£148	5	9

"The area under irrigation is 30 acres. Previous to the Local Board becoming the tenants of the land, the rent paid was 18*s*. per acre. The adjoining agricultural land is let at less than 1*l*. per acre rent. The average population draining to this area during the last year has been about 4,000. During the last month or two we have made provision to bring in a much larger area to this outfall, and in order to make provision for the increased population the Board has taken a sufficient area of land adjoining the present irrigation works at a rent of 10*l*. per acre. This will nearly double the existing area under sewage. It may also be interesting to the Commissioners to know that when the existing works at South Norwood were completed they were let to a tenant for three years, at a rent of 200*l*. per annum. The Board at this time paid the cost of distributing the sewage, so that as long as the works were let, there was a clear loss to the Board of 180*l*. per annum, but since they have taken them into their own hands a profit has accrued as will be seen from the foregoing figures."

A series of samples of raw sewage and effluent water has been taken from this land, giving the following results:—

RAW AND EFFLUENT SEWAGE.—NORWOOD.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Date of Sample.		Total solid Matter in Solution.	Organic Carbon.	Organic Nitrogen.	Nitrogen in Nitrites and Nitrates.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters. Mineral.	Suspended Matters. Organic.	Suspended Matters. Total.
February 25, 1869	Head -	91·70	3·235	·699	·000	2·030	2·371	8·60	3·68	6·36	10·04
	Tail -	73·20	1·577	·391	·423	·988	1·628	5·70	Trace.	Trace.	Trace.
March 12, 1869	Head -	117·80	5·407	2·294	·000	8·970	9·681	8·87	4·08	14·96	19·04
	Tail -	83·10	1·294	·184	·381	·965	1·360	8·87	Trace.	Trace.	Trace.
March 25, 1869	Head -	75·30	3·275	1·765	·000	7·097	7·610	8·50	5·88	8·36	14·24
	Tail -	97·80	1·061	·189	·462	·342	·933	7·50	Trace.	Trace.	Trace.

The relative cleansing which sewage undergoes by employment for irrigation at different seasons of the year has not yet received any sufficient elucidation. The proximity of Norwood and Croydon to London afforded a favourable opportunity of submitting the effluent water from the two sewage-farms to frequent investigation at all seasons of the year. Arrangements were, therefore, made for the periodical collection of samples for an entire year by our own laboratory man, in order to ascertain how far the efficient cleansing of sewage by this method is affected by the vigour or otherwise of vegetation, and especially whether the process could be relied upon during the winter months when plant life is in a comparatively dormant condition.

The following table contains the results of our periodical analysis of the effluent water from the sewage-farm at Norwood:—

EFFLUENT WATER.—IRRIGATED MEADOWS, NORWOOD.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description and Date of Collection.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.
Average composition of the sewage before irrigation	**94·9**	**3·972**	**1·586**	**6·032**	**·000**	**6·554**	**8·66**	—	—	—
Effluent water, September 24, 1868	81·7	1·621	·214	·013	·843	1·068	9·73	18·64	14·26	32·90
" October 8, "	95·3	1·516	·189	·006	·587	·781	9·93	15·84	22·14	37·98
" " 22, "	88·4	1·372	—	1·080	·710	—	9·93	17·68	16·70	34·38
" November 19, "	78·0	1·473	·285	1·366	·167	1·577	9·73	11·80	22·90	34·70
" December 3, "	79·6	1·258	·323	1·052	·694	1·883	8·54	4·18	27·74	31·92
" " 17, "	103·0	1·187	·120	1·254	·796	1·948	8·74	8·18	30·45	38·63
" " 31, "	77·8	1·291	·098	·497	1·450	1·957	6·75	9·30	25·56	34·86
" January 14, 1869	86·5	1·221	—	·721	·287	—	7·84	15·97	21·35	37·32
" " 21, " after two nights' frost	94·3	1·173	·265	·720	·088	·946	8·44	19·31	18·99	38·30
" " 25, " after seven nights' frost	100·3	1·431	·419	1·095	·072	1·393	10·13	24·23	16·37	40·60
" " 28, "	77·3	1·280	·406	1·195	·240	1·630	7·55	18·99	17·02	36·01
" February 11, "	83·8	1·130	·133	·300	·549	·929	6.80	20·30.	19·97	40·27
" " 25, "	73·2	1·577	·391	·988	·423	1·628	5·70	16·86	17·19	34·05
" March 12, "	83·1	1·294	·107	·965	·381	1·283	—	—	—	46·95
" " 25, "	97·8	1·061	·189	·342	·462	·933	7·50	16·54	20·93	37·47
" April 8, "	81·6	1·376	·321	·885	·547	1·596	8·00	19·68	17·16	36·84
" " 22, "	102·5	1·495	·260	·842	·081	1·034	8·80	19·32	20·34	39·66
" May 6, "	84·3	1·483	·410	1·131	·026	1·367	7·75	15·36	22·11	37·47
" " 20, "	83·0	1·602	·354	·730	·498	1·453	7·50	14·03	19·67	33·70
" June 3, "	97·1	1·683	·250	·415	·167	·759	9·64	17·80	20·92	38·72
" " 17, "	79·8	1·360	·221	·894	·000	·957	8·50	17·95	16·69	34·64
" July 1, "	95·1	1·577	·271	·905	·950	1·966	10·50	24·23	16·06	40·29
" " 15, "	94·0	2·160	·274	·408	·705	1·315	13·10	23·63	11·95	35·58
" " 29, "	93·6	1·889	·210	·135	·354	·675	10·20	20·77	17·01	37·78
" August 12, "	93·8	2·095	·339	·130	·608	1·054	11·80	20·91	14·36	35·27
" " 26, "	74·3	1·605	·370	·673	·000	·924	11·40	17·27	18·63	35·90
" September 9, "	89·2	2·085	·300	·300	·403	·950	10·90	19·91	16·93	36·84
" " 24, "	87·0	2·034	·517	1·128	1·390	2·836	10·60	17·50	16·37	33·87

These results, extending over an entire year, show that the effluent sewage was, except in a few instances, so far cleansed, even upon this heavy clay soil, as to be admissible into running water without nuisance. Two of these instances are instructive, since they occurred consecutively during and immediately after seven nights' frost, viz., in the samples collected on January 25th and January 28th, 1869. The frost was by no means severe, yet the organic nitrogen rose from ·098 to ·419 per 100,000 parts of effluent water, showing that the removal of offensive nitrogenous organic matter was partially arrested, and indicating that during a severe winter the purification of sewage upon a non-absorptive clay soil may be seriously interfered with. It is fortunate, however, that the admission of putrescible organic matter into streams during frosty weather is far less objectionable than it is when the temperature is higher, since the organic matter does not render the water offensive so long as a low temperature is maintained.

It is more difficult to account for the emission of exceptionally impure water from the Norwood Farm at other periods of the year, viz., on December 3rd, 1868, and February 25th, April 8th, May 6th and 20th, August 12th and 26th, and September 24th, 1869, but it probably arose, in some cases at least, from unpurified sewage gaining access to the drains through cracks in the soil.

The hardness of the effluent water was not excessive, although it exceeded considerably that of the water supplied to Norwood. It never contained more than traces of suspended matters.

12. *Croydon.*—At the Beddington meadows below Croydon, 260 acres of an open soil upon a gravelly subsoil have for the last seven years received the drainage water of from 30,000 to 40,000 people. The water-supply of Croydon and the copious land drainage of the place altogether yield a quantity of sewage equal to at least 3,000,000, sometimes exceeding 5,000,000 gallons daily. This passes through tanks where great pains were formerly taken to remove the solid and floating filth which it carried down, but less attention is now paid to this preliminary process, and the stream flows on very nearly as it leaves the town to the meadows in the occupation of Mr. Marriage, who, paying the rent at which the Board of Health have hired or bought the land, pays also a profit rent of 1*l.* per acre per annum for the use of the sewage. The success of sewage irrigation here as a deodorizing and cleansing process is complete, as the analyses show. There is never any lack of water, the soil is open, and has just slope enough to render easy the distribution of the liquid over it and through it, and there is sufficient fall between the top and bottom of the farm to allow the tail water of the upper fields to be spread a second time over fields below before it drains finally away. Very heavy crops of Italian rye-grass have been grown here. As much as 14 to 16 tons per acre are cut early in the month of May, and four or five cuttings a year are obtained, averaging from 8 to 10 tons each per acre. Mr. Marriage has also successfully used dressings of sewage in the cultivation of mangold wurzel ; and when wheat has been grown after sewaged grass, he has irrigated the field with advantage, even so late as the month of July, when the crop has appeared to be flagging and apparently suffering during a drought. Watercresses too have proved here an excellent crop for sewaging, not only from the profit derived from them, but from their cleansing powers upon the dirty liquid. The greater part of the land here irrigated is, however, in grass. That being the only crop which can be continuously watered with advantage, it is necessary to retain the greater part of the farm in grass in order that the enormous

quantity of dirty water here passing over the land may be changed from field to field often enough, and cleansed sufficiently before it leaves the land. Latterly, much of the land has been laid down to permanent grasses, which are better adapted for ordinary grazing purposes, and a large herd of feeding cattle have been successfully grazed upon these lands ; being moved from field to field as the water drains off them. This was, however, we presume, a temporary arrangement intended to diminish the tenant's costs as the expiry of his lease approaches, and not intended as an example of the best method of converting the fertilizing matter of sewage into valuable produce.

The following results of analysis illustrate the effect of irrigation when carried out upon the porous gravelly soil of the Beddington meadows. It will seen that the sewage as it flows upon the land possesses scarcely half the strength of average London sewage. The effluent water, even in the month of December, was satisfactorily cleansed and contained but mere traces of suspended matters.

Raw and Effluent Sewage.—Croydon.

Results of Analysis expressed in Parts per 100,000.

Description.	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								na l.	Organic.	Total.
Sewage as it flowed upon land, Dec. 23, 1869.	48·0	2·076	·749	2·684	0	2·959	4·39	1·96	6·64	8·60
Effluent water, Dec. 23, 1869	52·3	·795	·072	·265	1·164	1·454	3·70	Trace.	Trace.	Trace.
Sewage as it flowed upon land, Dec. 30, 1869.	48·0	2·882	1·269	2·700	0	3·493	4·30	3·80	10·80	14·60
Effluent water, Dec. 30, 1869	45·0	·772	·076	·530	·678	1·190	2·95	Trace.	Trace.	Trace.

The following table contains the results of our periodical analyses of the effluent water from these meadows, extending over an entire year :—

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description and Date of Collection.	Total Solid Matter in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.
Average composition of the sewage before irrigation	**45·7**	**2·508**	**1·576**	**3·005**	**·000**	**3·527**	**4·23**	—	—	—
Effluent water, September, 24, 1868 - - - - -	37·8	·723	·119	·006	·115	·239	2·73	21·03	5·93	26·96
" October 8, " - - - - -	37·9	·605	·120	·005	·382	·506	2·58	21·06	6·52	27·58
" " 22, " - - - - -	49·0	·644	·069	·008	·353	·429	3·18	19·10	7·70	26·80
" November 5, " - - - - -	39·9	·801	—	·248	·651	—	2·98	20·05	7·69	27·74
" December 3, " - - - - -	40·2	·766	·239	·534	·289	·968	3·77	22·57	7·55	30·12
" " 31, " - - - - -	48·7	·632	·124	·130	1·271	1·502	3·47	17·50	14·42	31·92
" January 14, " - - - - -	44·7	·604	·186	·166	·941	1·264	3·08	20·82	11·92	32·74
" " 21, " after two nights' frost -	46·0	·620	·242	·466	·210	·836	3·18	21·13	9·32	30·45
" " 25, 1869, after seven nights' frost -	45·1	·562	·235	·275	·686	1·147	2·58	18·50	10·67	29·17
" " 28, " - - - - -	34·5	·614	·093	·165	·425	·654	2·88	21·96	7·84	29·80
" February 11, " - - - - -	38·4	·979	·138	·125	·091	·332	2·70	20·24	10·21	30·45
" " 25, " - - - - -	39·9	·541	·089	·098	·776	·946	2·60	13·58	17·19	30·77
" March 12, " - - - - -	37·3	·545	·097	·246	·538	·838	2·30	—	—	27·58
" " 25, " - - - - -	38·8	·427	·077	·090	·596	·747	2·40	19·64	8·47	28·11
" April 8, " - - - - -	36·2	·637	·122	·150	·396	·642	2·50	19·61	7·90	27·51
" " 22, " - - - - -	39·1	·702	·129	·124	·241	·472	2·24	20·42	6·49	26·91
" May 6, " - - - - -	37·1	·758	·083	·032	·245	·354	2·45	21·98	4·93	26·91
" " 20, " - - - - -	37·1	·644	·080	·020	·284	·380	2·15	21·04	6·77	27·81
" June 3, " - - - - -	33·9	·531	·127	·062	·183	·361	2·40	18·40	7·90	26·30
" " 17, " - - - - -	29·1	·291	·082	·042	·000	·117	2·18	18·54	7·76	26·30
" July 1, " - - - - -	32·1	·761	·036	·050	·301	·378	2·28	20·05	5·36	25·41
" " 15, " - - - - -	38·1	·605	·124	·008	·201	·332	2·60	21·08	4·93	26·01
" " 29, " - - - - -	36·9	·628	·077	·090	·000	·151	2·60	20·93	7·48	28·41
" August 12, " - - - - -	39·1	·582	·385	·278	·325	·939	2·60	20·14	6·77	26·91
" " 26, " - - - - -	30·8	·362	·054	·018	·000	·069	2·80	17·89	6·92	24·81
" September 9, " - - - - -	32·7	·591	·105	·038	·147	·283	2·50	23·78	6·15	29·93
" " 24, " - - - - -	35·5	·606	·105	·068	·147	·308	2·44	15·23	5·21	20·44

These numerous analyses show that the sewage of Croydon is much more efficiently purified than that of Norwood. Only on one occasion (August 12th, 1869) during the entire year was the effluent water discharged in a somewhat unsatisfactory condition. On all other occasions the organic carbon and nitrogen were present in proportions considerably below those necessary to render the effluent water an offensive addition to a stream at any season of the year. Suspended matters were never present, except in minute quantity. It must be noticed, however, that during the continuance of the seven nights' frost in January 1869, the purification here, as at Norwood, became markedly impaired, the organic nitrogen increasing from ·186 part in 100,000, at which it stood before the frost, to ·242 part, whilst the assimilation of ammonia by the vegetation was also retarded, as is seen from the increased quantity of ammonia in the effluent water. Unfortunately, the winter of 1868–69 was too mild to permit of this point being satisfactorily tested, and it will therefore be desirable to resume these experiments should there be a longer continuance of frost during the winter of 1869–70. In order to show more clearly the condition of the effluent water from the Norwood and Beddington meadows at different seasons of the year, the following table has been prepared :—

INFLUENCE of SEASON upon the PURIFICATION of SEWAGE by IRRIGATION
RESULTS of ANALYSIS expressed in Parts per 100,000.

Average composition of effluent Sewage Water.	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.
Spring:							
Norwood - - -	88·1	1·500	·303	·816	·220	1·194	8·37
Croydon - - -	35·4	·594	·104	·072	·225	·388	2·32
Summer:							
Norwood - - -	88·6	1·883	·312	·462	·657	1·361	11·03
Croydon - - -	35·4	·607	·126	·069	·155	·300	2·57
Autumn:							
Norwood - - -	87·0	1·349	·203	·835	·734	1·629	8·94
Croydon - - -	43·1	·690	·138	·185	·589	·792	3·20
Winter:							
Norwood - - -	87·0	1·271	·273	·876	·313	1·255	7·71
Croydon - - -	40·6	·612	·145	·204	·533	·846	2·72
After seven days' frost:							
Norwood - - -	88·8	1·356	·413	1·145	·156	1·534	8·84
Croydon - - -	45·6	·591	·239	·371	·448	·992	2·88

It will be seen from the above table that the total solid matters in solution are remarkably uniform at all seasons; but in estimating the degree of purification effected at different seasons on the two farms, it is necessary to bear in mind the relative strength of the sewage employed in each season, since the purity of the effluent water is considerably affected by the proportion of polluting ingredients in the original sewage; in other words by the strength of that sewage. The strength of sewage is approximately given by the proportion of chlorine which it contains. Estimated by this standard the sewage of Norwood was strongest in summer, whilst the organic elements in the effluent water were also present in largest proportion during the same season. In winter, when the sewage was weakest, the effluent water was purest. At the Croydon farm, on the other hand, the sewage was strongest in autumn and winter, and the effluent water was also less pure in those seasons. In summer, when the sewage was weaker, the effluent water was also purer, whilst in spring, with a still more dilute sewage, the

water leaving the farm attained its highest degree of purity. It follows therefore that the cleansing of sewage is, in the absence of actual frost, less dependent upon season than upon the quality of the sewage itself. It is, however, far otherwise as regards the inorganic (and consequently non-polluting) fertilising constituents,—ammonia, nitrates, and nitrites. These compounds are, as might be expected, removed with greater avidity by vegetation in spring and summer than in autumn and winter. This is clearly seen from the following table, which shows the amount of nitrogen in these three forms left in 100,000 parts of the effluent waters in each of the four seasons, especially if the varying strength of the sewage above mentioned be taken into consideration :—

NITROGEN as NITRATES, NITRITES, and AMMONIA IN EFFLUENT SEWAGE.

—	Spring.	Summer.	Autumn.	Winter.
Norwood - - - -	·892	1·026	1·422	1·011
Croydon - - - -	·284	·212	·741	·701

Note.—DETAILS of the CROYDON SEWAGE-FARMS obtained 26th July 1876.

District in which the Lands are situate.	Area in Statute Acres.	
	Irrigated.	Not irrigated.
South Norwood, leased at 10*l.* 0*s.* 0*d.* per acre rental.	55	5
Beddington Farm, leased at 10*l.* 0*s.* 0*d.* per acre rental.	392	63
	447	68

ABSTRACT.

Acres irrigated - - - -	447
Do. not irrigated - - -	68
Total area - - -	515

515 acres of land at per acre rent 10*l.* = 5,150*l.*
Population of the districts, about 56,000.
Annual rateable value of the districts, about 275,000*l.*
Dry-weather flow of sewage used per day, about 3,500,000 gallons.
Storm-water flow, about 15,000,000 gallons.

N.B.—The rental paid for the land for ordinary agricultural purposes was from 26*s.* to 30*s.* per acre.

The crops grown are Italian ryegrass, mangold wurzle, cabbages, and other vegetables. The gross annual income has been about 8,000*l.*

The annual loss or costs in working the farms has been about 2,750*l.*, exclusive of the interest on the expenditure for laying out the farms.

13. *Woking.*—We refer, in conclusion, to an experiment in sewage irrigation on the slopes of poor sandy soil below the invalid prison at Woking. A population of more than 1,000 adults there receive a water-supply of upwards of 20 gallons a head, equal to about one ton daily to every 10 persons. The whole drainage of the place passes through a tank capable of holding about 1,500 cubic feet, or 40 tons of water ; and thence it has hitherto flowed almost entirely to waste, being used, however, in an unsystematic way, to fertilize the grass fields at the foot of the hill. Two acres upon the slope, in four consecutive plots apiece, were laid out in the spring of 1869, so that a tank-full could at any time be poured upon the upper or any other plot of the series, the tail water being directed on any other plot of the series lower down. The four plots of one acre were sown with Italian ryegrass in March, and three crops averaging more than 12 tons each were cut during the following summer, the plant having been repeatedly sewaged during the intervals. The other acre, lying in fallow, was sewaged in the same way, and samples of the effluent water have occasionally been taken both from plots growing ryegrass and from plots without a crop, in the hope that we should ascertain the increased power of a surface covered with a growing crop as compared with one which depended solely on the soil as a filter. The second acre has subsequently been planted with cabbages, potatoes, and mangold-wurtzel, and these crops have received sewage when the plants required. The difficulty of applying the results obtained here to the circumstances of any other case arises from the extreme hollowness and porosity of the Woking soil. A dressing of 40 tons of sewage, poured in three-quarters of an hour from the upper carrier of one of these quarter-acre plots, is, notwithstanding the steepness of the slope, almost all absorbed before it reaches the foot of the plot. It is only when the land is saturated with rain-water, and thus loses its power of absorption, that the sewage-water poured on at top, and conducted over the four plots in succession of the acre then being treated, will reach the bottom of the field. In the interests of the crop it has been therefore necessary to irrigate each plot in succession with raw sewage. The plan has generally been to give each acre so much sewage in the week as to make the result correspond to the allotment of an acre to every 100 persons throughout the year ; and in the further prosecution of the experiment here, when the soil shall have become more clogged with root fibre and with sediment, it is hoped that the effect of the whole acre upon a specified quantity of sewage may be realized and observed. The experiment has also to be extended to other places in order that we may learn from it, if possible, the maximum powers of various soils in cleansing sewage, getting results of the same definiteness in regard to irrigation, as our laboratory experiments have already given us with reference to filtration. Our results at Woking are still incomplete, and must be reserved till the issue of a later report; but it may be stated as regards the fertilising power of sewage water thus applied, that Italian ryegrass sown in March on poor Woking sand, yielded between July and October three crops of grass, averaging more than 12 tons per acre each ; and that on plots of similar soil the heaviest and most luxuriant growth of savoys, kale, and cabbage has taken place. A bed on which 20 tons of Woking peat had been laid one foot deep and watered in like manner, yielded as abundantly as the rest; and the result is sufficiently encouraging to justify the prosecution of the experiment on a larger scale, and on peat of a less questionable character, in order to ascertain, in the interests of the great Lancashire towns, whether sewage upon a true bog peat will feed succulent

vegetable growth as successfully as it is found to do on all other kinds of soil.

The Rivers Pollution Commissioners conclude their remarks on some chemical modes of treating town-sewage as under. Irrigation is the only power of cleansing sewage which has stood the test of experience, and, unless it be extensively adopted, there is but little hope of any substantial improvement in our sewage-polluted rivers.

Contrast the chemical methods with the efficiency of irrigation as a utiliser of the manure ingredients of town-sewage. All these ingredients are in this case taken to the land; and three-fourths of them in winter, four-fifths or five-sixths of them in summer, are left there for the use of growing plants; the remainder being rendered unoffensive. These manure materials are thus carried, distributed, and buried; and thus, without the costly labour of the dung cart, manure distributor, or plough, they are brought to the very roots they are to feed; and the fertility they accordingly produce is unexampled otherwise in English agricultural experience. The process can be carried on without offence to any but those who go close to the tanks or channels; and it can be conducted, as the experience of many years at Edinburgh and Croydon proves (*see* Report on *Mersey* and *Ribble* basins, Vol. I., p. 90), without injury to health. We have therefore no hesitation in recommending irrigation as the only plan of dealing with the sewage difficulty at present known to us which at once abates a nuisance and turns to profitable account an otherwise valueless material.

Influence of Sewage Irrigation on Health.

It has often been asserted that sewage irrigation has a detrimental influence on the health of persons living near to or working upon sewage-farms; but nowhere have we found instances of ill-health that are properly attributable to malaria or other causes due to irrigation; and the evidence of Dr. Littlejohn, medical officer to the Board of Supervision in Scotland; Sir Robert Christison, Bart., M.D.; Dr. Ligertwood, staff surgeon; Dr. Alfred Cresswell, and Dr. Alfred Carpenter, given before the Rivers Pollution Commission (see Report, Mersey and Ribble Basins, 1870, pp. 90–91), fully confirms this.

The Craigentinny Meadows.—After bearing testimony to the health of the village of Restalrig, which is surrounded by the sewage meadows of Lochend and Craigentinny, Dr. Littlejohn says:—"I expected that the first part of Edinburgh (Regent Terrace and Carlton Terrace), against which the wind blowing over these meadows impinges, would have exhibited evidence of infection in the shape of cholera or typhoid fever; but I have totally failed to find it so. There are also at Marionville, which is in the very centre of the meadows, a collection of children of the poorest class, who have been kept under the auspices of Dr. Guthrie. Thus the soldiers in the barracks (on the one side, the old people at Restalrig midway, and the very young children with debilitated constitution on the other side) are healthy, With these three delicate tests, including Regent Terrace and Carlton Terrace, we have failed to show that the meadows are prejudicial to health; in fact, opposite evidence might be obtained of a very strong kind."

Dr. Littlejohn informed one of us in January 1876 that he had not anything to add to or retract from the evidence he gave before the Rivers Pollution Commission.

Sir Robert Christison, Bart., M.D., President of the Royal Society

of Edinburgh, in an address on public health in October 1863, speaking of the influence of sewage irrigation on health, said :—" The irrigated meadows in the immediate neighbourhood of Edinburgh, with foul water, are ague-free. They might with reason be strongly suspected, for as managed they present that frequent alternation of considerable moisture and approach to dryness, that rankness of vegetation, and that abundance of decaying organic matter which are thought when combined eminently to foment intermittent and remittent fevers in countries liable to these diseases; but if there be any doubt as to the general salubrity of the now famous meadows of Craigentinny, there is none at least as to the total absence of ague among the inhabitants. I have recently been making careful inquiry respecting this famous and somewhat unsavoury institution. Many years ago my own prejudices were all against the meadows. I have been compelled to surrender them. I am satisfied that neither typhus or enteric fever, nor dysentery nor cholera is to be encountered in or around them, whether in epidemic or non-epidemic seasons, more than in any other agricultural district of the neighbourhood. I think it right in reference to the late introduction of the Craigentinny system of irrigation into the vicinity of other large towns, that these precise facts should be known."

Sir Robert Christison writes to the Secretary to the Commission on the 4th of February 1870, " I have nothing to add to or subtract from the extract from my Social Science address in 1863, quoted above."

Croydon (South Norwood) Sewage-Farm.

" Dr. Alfred Cresswell in his evidence says :—I have resided in the neighbourhood of the South Norwood Sewage Farm since 1866, and have the largest practice there, especially attending the families of those who work on the farm, and who live in houses within 150 yards of the sewage fields. There is also a large school for girls near to the farm. In this school, in which there are more than 30 inmates, there has not been a single case of illness from preventible diseases, and my last quarter's bill was *5s. 6d.* I have not been able to trace a single case of illness to the sewage fields. An unpleasant effluvia does exist, but it is so seldom perceptible that a house built within 200 or 300 yards would command the same rent as if half a mile off. My investigations and independent observations during the last three years have made me an advocate for this method of utilising sewage matter; and as an instance of how perfectly the watery portion is purified, I can state that the water flowing over these fields and thence conducted into the brook is frequently drank by persons who are ignorant of its source. It is clear, pellucid, and tasteless. Therefore, after watching the working of these fields, my opinion is that when the system of sewage irrigation is well managed the health of the inhabitants in the immediate vicinity is in no way influenced by it."

Croydon (Beddington) Sewage-Farm.

" Dr. Alfred Carpenter says :—The visitor to Beddington will see a number of villas which have been occupied for some years, with irrigated fields both in front and rear, whilst not a trace of enteric disease has appeared in any of them, though I think the Beddington farm is capable of much improvement. It is a farm of nearly 300

acres, lying to the west of the town, and is within 500 yards of a populous portion of it, and also within 900 yards of the centre of the place ; and yet I can safely say that the continuance of a west wind is always accompanied by a diminished amount of ordinary sickness in the place, and our ordinary mortality is generally below 20 per 1,040 At Norwood the population is much greater and much nearer to the fields than at Beddington, probably 400 persons living within 200 or 300 yards of the farm. Previously to its establishment in that district fever abounded ; since then that disease has all but disappeared and the mortality of the district has steadily declined."

Sewage-grown Grass is Wholesome.

On the Liability to Disease which has been alleged to exist from the Consumption of the Milk and Flesh of Cattle fed on Sewage-grown Vegetables.

Dr. Henry D. Littlejohn, in his evidence before the Rivers Pollution Commission at Edinburgh, on September 23rd, 1870, said :—"There are a considerable number of cows kept in Edinburgh and the immediate neighbourhood, and a large quantity of milk is consumed, chiefly obtained from these cows. They are fed with grass that is grown on the Craigentinny meadows. I was of opinion that such grass might be of inferior quality, but I have failed to detect any bad effects resulting from its use. Entozoic disease is remarkably rare in Edinburgh, and tapeworm is hardly ever heard of, except in the cases of persons coming from other places to reside here. Many of the cows which have been fed upon sewage-grown grass are used as food. They are not fattened, because they are always kept in such capital condition; but the cows which have been so fed find their way to our slaughter-houses, where they are examined by inspectors and myself, and, so far as my observations have gone, the use of sewage grass for the food of animals is unobjectionable. Trichiniasis is not known in Edinburgh. If there had been anything in the idea that sewage grass would lead indirectly to entozoic disease, it has had plenty of time to develope itself, and Edinburgh is not only the seat of a great medical school, but medical observation is carried to the highest point so that it could not fail of being detected."

APPENDIX No. VI.

List of Patents more or less connected with Sewage and Manures.

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1856	6	Alexander Cochrane -	Conveying and collecting sewage water, &c.
„	212	Edward Vincent Gardner -	Apparatus for heating, drying, evaporating, &c.
„	974	Thomas Squire and Charles Frederick Claus.	Artificial manure.
„	1288	William Needham and James Kite.	Expressing moisture from substances.
„	1579	James Alexander Manning -	Manure.
„	1815	Thomas Wicksteed -	Sewage.
„	1982	George Warriner - -	Compound for preserving, deodorizing, and fertilizing.
„	2003	Charles Durand Gardissal -	Manure.
„	2159	Stanislas Chodzko - -	Manure.
„	2273	Jean Francois Victor Larnaudes.	Antiseptic and disinfecting mixture.
„	2289	Duncan Bruce - -	Manure.
„	2333	John Gedge - -	Mineral manure.
„	2560	Francis Cook Matthews -	Manure.
„	2689	Edward Money - -	Manure.
„	2918	Anne Marie Macé - -	Manure.
„	2924	Frederick Oldfield Ward and Frederick Wynaut.	Manures.
„	3000	Joseph Bower - -	Manufacture of manure.
1857	49	Frederick Herbert Maberly -	Receptacles for sewerage.
„	114	Sir James Murray - -	Deodorizing sewage matters, manufacture and distribution of manures, &c.
„	443	James Taylor - -	Manure.
„	862	John Ward - -	Manure.
„	983	Jean Francois Victor Larnaudès.	Disinfecting and deodorizing animal and vegetable substances.
„	992	Jasper Wheeler Rogers -	Apparatus for the collection of night soil and drainage of houses.
„	1004	Augustus Edward Schmersahl	Treating bones to obtain gelatine, size, glue, &c.
„	1069	Thomas Richardson and Manning Prentice.	Manure.
„	1591	Frederick Oldfield Ward and Frederick Wynauts.	Manufacture of manure, &c.
„	2206	Robert Clark Gist - -	Manufacture of manure.
„	2220	John McMaster and William Wilson.	Manufacture of manure.
„	2438	Richard Archibald Brooman	Decomposing soapy wash waters, &c.
„	2627	Edward Owen - -	Manure.
„	2645	Charles Walker - -	Manufacture of manure.
	2949	William Thomas Manning -	Treatment of sewerage, &c.
„	2980	Jean Baptiste Cony -	Manufacture of manure and disinfection of animal and vegetable matters.

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1857	3023	Frederick Oldfield Ward -	Manufacture of manure, &c.
„	3131	Francis Taylor - -	Closets or privies.
1858	61	James Alexander Manning	Treatment of sewage and other polluted liquids.
„	171	Charles Neillon - -	Manufacture of manure from sewage matters.
„	179	James Alexander Manning	Manufacture of manure.
„	188	William Edward Newton -	Obtaining and applying compounds of nitrogen.
„	199	Leon Salles de la Magdaleine	Manure.
„	287	George Lindsey Blyth -	Manure.
„	354	Edward Toynbee - -	Manufacture of manure.
„	400	John Hadfield - -	Manufacture of manure and other products from sewage matters.
„	665	Isaac Brown and John Brown	Manure.
„	703	Thomas Greenshields -	Treating ammoniacal liquor, &c.
„	733	Herman Schwietzer, Joseph Holder, and John Broughton.	Manure.
„	1245	Robert Owen - -	Waterclosets, night commodes, &c.
„	1456	James Cane Coombe -	Manufacture of manure from fœcal and other matters.
„	1499	John Chisholm - -	Treating sewage and other matters, &c.
„	1549	Constantine Nicolaus Kottula	Manufacture of manure.
„	1616	Richard Archibald Brooman	Apparatus for the reception and treatment of sewage.
„	1620	Charles Fréderic Vasserot -	Manure.
„	1664	William Parsons - -	Separating the solid matter from sewage waters.
„	1793	Charles Felton Kirkman -	Treating sewage, &c.
„	1817	Thomas Pickford - -	Manure.
„	2073	Jean Baptiste Adolphe Dugléré.	Separating solids from liquids for the purpose of disinfection.
,	2451	Charles Finlay Oliphant Glassford.	Manure.
„	2977	Thomas Pickford - -	Manure.
1859	183	Thomas Richardson -	Manure.
„	184	Samuel Osler and John Barton Balcombe.	Manure.
„	195	André Jacques Amand Gautier, Jean Gilbert Dumay, and Jean Theodore Persin	Manure.
„	313	Alexander Gopsell Pooley -	Apparatus for manufacturing manure.
„	447	Prederick William Emerson	Treating ores of lead, &c.
„	539	The Rev. Henry Moule -	Apparatus for the evaporation of sewage and other waters, &c.
„	648	John Samuel Dawes -	Collecting night-soil for agricultural purposes.
„	778	Thomas Carr - -	Machinery for disintegrating artificial manures, &c.
„	879	Marc Antoine François Mennons.	Treatment of mineral phosphates.
„	1220	William Edward Gedge -	Manure.
„	1280	Joseph Gibbs - -	Treatment of coal, &c. for the manufacture of manure.
„	1368	John Henry Johnson -	Machinery for reducing solid substances to powder.
„	1388	William Bryer Nation -	Manufacture of superphosphate of lime.
„	1559	Thomas Bell - -	Manure.

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1859	1567	Bridge Standen - -	Manure.
,,	1843	John Dyer Bryant -	Superphosphate of lime.
,,	1944	Michael John Stark -	Manure.
,,	2107	Nathaniel Heckford -	Purifying rivers and treating night-soil.
,,	2157	John Dales - -	Purification of sewage and other waters, &c.
,,	2200	Patrick Robertson - -	Manure.
,,	2218	William Henry Buckland -	Preparation of peat.
,,	2270	George Long and James Archer.	Manure.
,,	2450	John Armour - -	Apparatus for measuring and regulating the supply of substances in preparing mixtures or compounds.
,,	2460	Henry Phillips and James Bannehr.	Manure.
,,	2526	William Mannix - -	Manure.
,,	2545	William Clark - -	Compound for preserving and disinfecting organic substances.
,,	2958	Alexander McDougall -	Preparation of disinfecting and antiseptic substances.
1860	23	Marc Antoine François Mennons.	Fertilizing compounds.
,,	73	Archibald Brounlie -	Treatment of sewerage matters.
,,	232	Thomas Walker - -	Cleansing sewage and other waters.
,,	404	Joseph Arnold - -	Manure.
,,	703	Thomas Richardson -	Treating organic substances containing phosphate of lime.
,	908	Jasper Wheeler Rogers -	Collecting excrement and facilitating drainage.
,,	1343	James Alexander Manning	Treating sewage, &c.
,,	1463	Richard Archibald Brooman	Desiccating fecal matters, &c.
,,	2023	William Clark - -	Manure.
,,	2246	William Edward Gedge -	Manure.
,,	2296	Thomas Richardson Manning Prentice.	Treating phosphotic matters, &c.
,,	2482	Jasper Wheeler Rogers -	Apparatus for collecting excrement and draining houses.
,,	2777	Mathieu Louis Henrionnet and Leopold Octave Boblique.	Treating mineral phosphates of lime.
,,	2848	George Henry Cail -	Manure.
1861	249	Henry Phillips and James Bannehr.	Urinals; manufacture of manure.
,,	424	Thomas Richardson -	Manure.
,,	684	Jacob Jervell - -	Manure.
,,	876	Francis Taylor - -	Apparatus for receiving, drying, and deodorizing human excrement.
,,	1019	Charles Stevens - -	Artificial manure.
,,	1276	Frederick Oldfield Ward -	Manure, &c.
,,	2159	Alexandre Jaille - -	Manure.
,,	2229	Charles Felton Kirkman -	Obtaining manure from sewage.
,,	2351	John Oliver, John Grantham, William Linnock, and Montague Richard Leverson.	Obtaining chemical substances; treatment of vegetable fibre, &c.
,,	2525	Thomas Tidmarsh - -	Manure.
,,	2540	Charles Noyes Kernot and Martin Diederich Rucker.	Obtaining ammoniacal salts, &c.

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1861	2871	Frederick Robert Hughes and Thomas Richardson.	Treating saline compounds.
	3265	Thomas Pickford - -	Manure.
1862	338	Marc Antoine François Mennons.	Treating phosphates of lime.
„	378	Ditto.	Disinfecting animal excretions.
„	587	Bridge Standen - -	Manure, &c.
„	807	Michael Henry - -	Kilns, ovens, and furnaces.
„	908	William Clark - -	Manure.
„	1188	William Edward Newton -	Fertilizing composition.
„	1409	James House - -	Crushing and reducing substances.
„	1623	William Footman - -	Treating sewage.
„	2073	Alexander Morrison Fell -	Manufacture of sulphate of ammonia and manure.
„	2082	Joseph Daniels. - -	Artificial manure.
„	2097	William Clark - -	Manure.
„	2201	John Richard Nichol -	Utilizing and disposing of the sewage of towns and villages.
„	2669	John Harrop and James Wadsworth.	Deodorizing refuse and fœcal matters for manure.
„	2712	John Beale and Mary Anne Beale.	Manure.
„	3011	William Clark - -	Utilizing refuse azoted matters.
„	3132	Thomas Walker - -	Utilizing sewage, &c.
„	3317	Edward Toynbee - -	Extracting oils and fatty matters from shoddy, &c. and producing artificial manure.
„	3449	John Platt and William Richardson.	Disinfecting or pulverizing artificial manures, &c.
1863	132	John Harrop - -	Manure.
„	321	James Alexander Manning -	Treating night-soil, &c.
„	606	Thomas Henry Morrell and Joseph Williamson.	Purifying noxious vapours from night-soil, &c.
„	731	William Lorberg - -	Treating rags.
„	761	William Clark - -	Preparation of manure, &c.
„	967	Robert Calvert Clapham -	Treating waste liquors.
„	1362	William Clark - -	Manure.
„	1435	Henry Martin - -	Manure.
„	2208	Thomas Henry Baker and George Friend.	Treating excrementitious and sewage matters.
„	2294	William Lorberg -	Treating rags.
„	2724	Guillaume Ville - -	Treating natural phosphates of lime for agricultural purposes.
„	2731	Jean Augustin Barral and Louise Adolph Cochery.	Manure.
„	2947	Thomas Carr - -	Amalgamating, agitating, and dissolving materials.
„	3152	John Wright - -	Manufacture of superphosphate of lime.
„	3264	John Maynes - -	Manure.
1864	592	Edward Bishop and William Bailey.	Evaporating the water from fœcal matter.
„	595	James Lee Norton - -	Manure.
„	597	John Thomas Way - -	Manure.
„	773	James Robbins - -	Treating substances for producing manure.
„	955	James Cane Coombe -	Manure.
„	1024	George Jarvis Worssam -	Expressing liquids and moisture from substances.
„	1191	Thomas Walker - -	Utilizing sewage.

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1864	1408	Thomas Walker - -	Preparing phosphates of ammonia, &c.
,,	2072	Francis Taylor - -	Apparatus for receiving, drying, and deodorizing human excrement.
,,	2329	Thomas Walker and Thomas Ferdinand Walker.	Utilizing sewage.
,,	2788	James Alexander Manning -	Collecting and treating night-soil.
,,	2832	George Edward Noone -	Deodorizing and utilizing sewage.
,,	2840	Jacques Jules Renous Céré	Manure.
,,	3115	William Bardwell - -	Utilizing sewage, &c.
,,	3160	Henry Bird - -	Treating sewage matters.
,,	3161	Stephen Pierre André de Brocalde D' Elüza.	Manure.
,,	3256	Thomas Richardson -	Manure.
1865	202	Benjamin King - -	Manure.
,,	451	Richard Smith - -	Treating sewage and ventilating sewers.
,,	512	William Edward Newton -	Artificial manures.
,,	893	William Moxon Fuller -	Reducing waste for manure.
,,	1877	Donald McCrummen -	Artificial guano.
,,	1935	Thomas Spencer - -	Compounds for promoting vegetation.
,,	2626	John Linton - -	Utilizing sewage.
,,	2808	Henry Young Darracott Scott.	Treating and deodorizing sewage water.
,,	2830	George Bartlett - -	Artificial manure.
,,	3115	John Thomlinson - -	Disinfectants.
1866	101	Francis Sutton - -	Treating sewage and urine.
,,	191	Adolphe Francois Mineur -	Manure.
,,	642	Victor Larnaudès - -	Disinfecting and preserving fluid.
,,	773	Alfred George Lock -	Manure.
,,	898	Charles Thieme Liernur -	Collecting sewage, &c.
,,	921	James Davis - -	Utilizing and preventing decomposition of substances.
,,	949	Alfred George Lock -	Manure.
,,	1026	George William Skinner -	Utilizing sewage.
,,	1163	George Edward Noone -	Deodorizing and treating sewage, &c.
,,	2107	Adolph Kühne - -	Purifying water, &c.
,,	2218	Robert Irvine - -	Treating and purifying water.
,,	2606	George William Skinner -	Utilizing sewage.
,,	2750	Francis Taylor - -	Apparatus for receiving, drying, and deodorizing human excrement.
,,	2926	Henri Adrien Bonnneville -	Manure.
,,	2988	James Conyers Morrell -	Dry closets, &c.
,,	3296	Thomas Hoey - -	Flushing waterclosets, &c.
,,	3401	William Bradburn - -	Treating excrementitious matters, &c.
1867	119	Ernst Süvern - -	Purifying factory and sewage waters.
,,	579	William Parry and John Frearson.	Treating sewage.
,,	729	James Conyers Morrell -	Dry closets.
,,	788	Alfred Henry Hart and William Parry.	Treating sewage.
	933	William Clark - -	Manure.
,,	1229	Emile Grienin - -	Disinfecting fecal matters.

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1867	2549	Frederick Tolhausen -	Disinfecting fecal and manuring matters, &c.
"	2894	Thomas Henry Baker and Thomas Woodroffe.	Treating and purifying sewage.
"	2918	James Bannehr - -	Supplying deodorizing material to closets, and treating liquid excreta.
"	3566	Alexander Melville Clark -	Extracting ammonia from fermented and other liquids, &c.
1868	510	William John Bennett and John Jobson.	Filtering sewage, &c.
"	566	Pierre Nicholas Goux -	Treating and utilizing excreta.
"	744	William Knox Stuart -	Treating and utilizing sewage.
"	1954	William Cameron Sillar, Robert George Sillar, and George William Wigner.	Deodorizing sewage for manure.
"	2666	John Yule - - -	Removing sewage.
"	2667	William Shang - -	Separating sewage.
"	2883	William Henry Hughan -	Treating and deodorizing sewage, &c.
"	2919	Edward Henry Prentice -	Treating sewage, &c.
"	3087	James Dewar - -	Manure.
"	3203	Gavin Chapman - -	Treating sewage.
"	3341	Sigismund-Schuman -	Waterclosets.
"	3390	Alexander Melville Clark -	Filtering sewage, &c.
"	3457	Charles Jones - -	Treating sewage.
"	3562	Thomas Smith and John Van Norden Bazalgette.	Deodorizing and manufacturing manures from sewage, &c.
"	3714	Alexander Melville Clark -	Compound for disinfecting sewage, &c.
"	3914	Josiah George Jenning -	Treating sewage and irrigating land.
1869	506	Frederic Delbreil - -	Removing sewage, &c.
"	791	Josiah George Jennings -	Preparing sewage for irrigating.
"	815	James Carter - -	Disinfecting and deodorizing fecal matters, &c.
"	826	John Thomas Darke -	Treating sewage.
"	982	Joseph Caldwell Lee -	Collecting and treating excreta.
"	1103	Edward Charles Cortis Stanford.	Applying, treating, and utilizing materials for deodorising.
"	1352	Charles Thieme Liernur -	Removing and utilizing sewage.
"	2016	John Hart - - -	Separating, distributing, and utilizing sewage.
"	2269	John Henry Johnson -	Manure.
"	2623	Friedrich Wicke, Julius Brönner, Theodor Petersen, and Johann Georg Zehfuss.	Treating excreta for manure.
"	3129	Francis Taylor - -	Drying excrement.
"	3550	Mark French Anderson -	Treating sewage for manure.
1870	67	William Henry Hughan -	Treating sewage, &c.
"	239	Maxwell Anketell and Oliver Frederick Anketell.	Manufacturing manure and fuel from sewage, &c.
"	364	George William Wigner -	Treating and purifying sewage.
"	506	John Leopard - -	Treating and filtering sewage.
"	580	Alexander Bobrownicki and Alfred Didier Marie Mesnard.	Fuel and manure.
"	607	David Forbes and Astley Paston Price.	Treating sewage.

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1870	630	James Conyers Morrell -	Treating sewage.
„	679	George William Wigner -	Centrifugal drying machines.
„	1061	Thomas James Smith -	Treating sewage, &c.
„	1137	David Forbes and Astley Paston Price.	Treating sewage and producing manure.
„	1200	Ludwig Schad - -	Treating excrement.
„	1311	Robert Weare - -	Treating sewage, &c.
„	1314	Astley Paston Price -	Treating sewage.
„	1354	George William Wigner -	Deodorizing and purifying sewage, &c.
„	1706	Bevan George Sloper -	Treating sewage.
„	1949	Peter Spence - -	Treating sewage.
„	2032	Henry Malcolm Ramsay -	Treating sewage, &c.
„	2047	John Hughes Lloyd -	Utilizing and deodorizing sewage matters.
„	2048	Charles Bartholomew -	Treating sewage.
„	2297	Joseph Judge Harp -	Purifying and utilizing sewage.
„	2534	Ferrar Fenton and Samuel Hollins.	Treating sewage, &c.
„	2653	Charles Felton Kirkman -	Treating sewage.
„	2832	William Frost Sweetland and John Merfield.	Purifying sewage.
„	2838	Joseph Judge Harp -	Treating sewage.
„	3107	Amos Bryant and Samuel Hall Culley.	Deodorizing and treating sewage, &c.
„	3167	Fritze Hillé - -	Manufacture of deodorizing and disinfecting compounds, treatment of sewage, &c.
„	3169	Henry Young, Darracott Scott.	Treatment of sewage, &c.
„	3269	Frederick Ludewig, Hahn Danchell.	Treating of sewage.
„	3399	Christopher Rawson, Philip Ovenden, James Wylde, William McCree and Henry Hill.	Deodorizing and purifying sewage, &c.
1871	297	Proctor Sherwin and John Maude Sutton.	Treating sewage matters, &c.
„	329	Bevan George Sloper and Felix Jean Joseph Washer.	Treating sewage.
„	351	Charles Baly - -	Treating sewage, &c.
„	804	Richard Dover - -	Treating sewage.
„	1269	Frans Julius Fahlman -	Disinfecting fecal matter.
„	1469	Adolphus Videky - -	Separating solid from liquid excreta.
„	1897	Ferrar Fenton - -	Treating sewage, &c.
„	1969	Edward Taylor - -	Treating excreta, &c. for manufacturing manure.
„	2109	James Beckett and John James Cam.	Treating sewage.
„	2140	James Irvine Lupton -	Treating sewage.
„	2243	Henry Young Darracott Scott.	Treating sewage.
„	2274	Henry Bright - -	Drying sewage, &c.
„	2481	Francis Parry. - -	Drying precipitated sewage, &c.
„	2495	James Banks and William Walker.	Treating and filtering sewage water, &c.
„	2567	Charles De Chastelain -	Collecting and filtering sewage.
„	2569	James Burrow - -	Treating sewage, &c.
„	2696	Robert Milburn and Thomas Browning.	Drying and treating sewage deposit &c.
„	2760	James Brough Pow -	Treating sewage.

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1871	2841	Daniel Wilks - -	Collecting and utilizing animal refuse, sewage, &c.
"	2878	Bendedict John Angell -	Treating seaweed.
"	2926	Adolphe Pierre Vassard -	Treating liquid sewage, &c.
"	2975	Job Cole and William Abbott.	Treating and utilizing sewage. &c.
"	2997	Hugh Smith - -	Treating sewage.
"	3060	William Henry Hughan -	Manure.
"	3233	François Jules Fahlman -	Apparatus for treating sewage, &c
"	3436	James Alfred Wanklyn -	Utilizing sewage ammonia.
"	3515	Henry Young Darracott Scott.	Treating sewage water
1872	379	Francis Gerard Prange and William Whitthread.	Utilizing sewage.
"	388	Alexander Melville Clarke -	Treating sewage, &c.
"	448	Silvester Fulda - -	Clarifying waters, &c.
"	465	David Carter - -	Dry earth closets.
"	575	William Cameron Sillar and Robert George Sillar.	Treating sewage.
"	671	Robert Blackburn - -	Treating sewage.
"	742	John Bailey Denton and Rogers Field.	Regulating intermittent filtration of sewage and irrigation.
"	849	Henry Young Darracott Scott.	Treating sewage water.
"	926	Arthur Charles Henderson -	Distilling and filtering fecal matters.
"	944	Dugald Campbell - -	Treating sewage, &c.
"	955	William Weldon Symington	Measuring the flow of sewage, &c.
"	1065	Leos Antoine Badin -	Manure.
"	1327	Thomas Christy the younger	Treating ammoniacal liquor, &c.
"	1421	James Robey - -	Filtering medium, &c.
"	1577	Andrew John Murray -	Treating sewage deposits.
"	1806	William Cameron Sillar, Robert George Sillar, and Christopher Rawson	Treating animal matters.
"	2141	Henry Syed Copland -	Apparatus for mixing and precipitating sewage, &c.
"	2266	Robert Milburn and Henry Jackson.	Drying and pulverising manure cement, &c.
"	2279	Isaac Brown - -	Treating sewage.
"	2496	Millington Henry Synge -	Deodorizing apparatus.
"	2538	Henry Young Darracott Scott.	Treating sewage.
"	2687	Bridge Baron Standen -	Collecting and treating excrementitious matters.
"	2991	William Ashop - -	Drying sewage.
"	3028	Henry Young Darracott Scott.	Treating sewage.
"	3215	John Lewis Felix Target -	Receivers for waterclosets.
"	3348	Rogers Field - -	Sewage tanks.
"	3355	Henry Young Darracott Scott.	Treating sewage deposits, &c.
"	3356	James Alexander Manning	Treating fecal matters.
"	3412	Gustav Alsing - -	Treating night-soil, &c.
"	3464	Edwin Hills and Benjamin Biggs.	Treating sewage.
"	3529	David Curror and James Dewar.	Purifying fluids and manufacturing manures.
"	3670	Henry Young Darracott Scott and Thomas Walker Scott.	Preparing lime for treating sewage.
"	3734	William Hart and James Hart.	Drying sewage precipitates, cement, pulp, &c.

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1872	3755	Henry Young Darracott Scott.	Treating and utilizing sewage water.
„	3788	Charles Denton Abel -	Conveying sewage from cesspools, &c.
„	3805	John Rendall and William Rendall.	Slop carts.
„	3821	John Lewis Felix Target -	Collecting and disinfecting sewage excreta.
„	3843	George Haseltine - -	Rendering and drying animal matter, &c.
„	3882	William White Fereday -	Treating excreta for conversion into manure.
„	3913	Leos Antoine Badine -	Closets and apparatus for collecting fœcal matters.
1873	154	Henry Young Darracott Scott.	Treating sewage.
„	168	John Lewis Felix Target -	Treating excreta and sewage.
„	187	Edward Charles Hamilton, William Richard Preston, and Henry Jones.	Manure.
„	230	James Robey - -	Charcoal for purifying sewage, &c.
„	266	Frederick Jacobsen -	Treating sewage.
„	331	Baldwin Latham - -	Purifying sewage.
„	499	George Frederick Chantrell	Receptacle for house refuse, &c.
„	513	Hugh Campbell - -	Manufacture of manure.
„	556	Francis Henry Atkins -	Filtering apparatus.
„	570	Henry Young Darracott Scott.	Treating excreta.
„	712	Thomas Hoey - -	Watercloset apparatus.
„	912	Robert Stevenson Symington	Apparatus for dealing with sewage, &c.
„	957	James Robey and George Frederick Chantrell.	Filtering and deodorizing medium.
„	1319	Gustav Alsing - -	Treating sewage, &c.
„	1445	Henry Young Darracott Scott.	Treating sewage.
„	1509	Do. - - -	Do.
	1555	Walter Brown - -	Treatment of sewage.
„	1686	Eugene Moriarty - -	Treating sewage.
„	1885	Benjamin Green - -	Storing and treatment of sewage.
„	1967	Joseph Townsend - -	Treating sewage.
„	2071	John Leigh - -	Treating sewage, &c.
„	2317	Jeremiah Marsden and John Collins.	Treating sewage.
„	2442	Robert Knott - -	Treating sewage, &c.
„	2450	Edward Charles Hamilton and William Richard Preston.	Artificial manure.
„	2454	Frederick Jacobsen -	Purification of sewage, &c.
„	2532	William White - -	Treating sewage.
„	2534	James Robey - -	Do.
„	2581	John Stephens - -	Treating excreta, &c.
„	2638	John Leigh - -	Manufacture of manure.
„	2662	Christopher Rawson, William Cameron Sillar, John William Slater, and Thomas Sipling Wilson.	Manufacture of manure.
„	2760	William Henry Hughan -	Treating sewage.
„	2791	Rupert Goodall - -	Treating and clarifying waste water from fulling mills, &c.
„	3168	Charles Thieme Liernur -	Pneumatic drainage works.

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1873	3169	William Whitthread -	Disinfectant and oxydizing agent.
„	3331	John Towle - -	Treating sewage.
„	3541	John Hewitt Milnes -	Utilizing sewage.
„	3632	Alexander Colvin Fraser and William Watson.	Treating and utilizing sewage.
„	3742	Henry Young Darracott Scott.	Treating sewage water.
„	3781	William White - -	Precipitating sewage and other foul waters, &c.
„	3833	Benjamin Green - -	Storing and treating sewage.
„	4092	Henry Malcolm Ramsay -	Treating sewage.
„	4284	John James Bodmer -	Drying peat, sewage deposit, &c.
1874	50	William Alfred Gibbs -	Drying apparatus.
„	160	Augustus Edward Schmersahl.	Treating sewage.
„	283	Henry Young Darracott Scott and John Berger Spence.	Treating sewage, &c.
„	653	Henry Young Darracott Scott.	Treating sewage for manure.
„	848	Rupert Goodall - -	Purifying foul water or sewage.
„	1171	Thomas Short - -	Purifying sewage.
„	1415	William Robert Lake -	Deodorizing and utilizing sewage.
„	1426	John Towle - -	Collecting, treating, and distributing sewage.
„	1453	Daniel Kinnear Clark -	Disintegrating and straining apparatus.
„	1689	Gustav Alsing - -	Utilizing sewage for manufacturing artificial fuel.
„	1764	John Howard Kidd -	Deodorising sewage and making artificial manure.
„	1826	Rupert Goodall - -	Clarifying sewage, &c.
„	1916	John Henry Johnson -	Filtering sewage, &c.
„	1959	William Henry Hughan -	Treatment of sewage, &c.
„	2408	Samuel Hallsworth and Richard Bailes.	Clarifying waste water, sewage, &c.
„	2439	Augustus Edward Schmersahl.	Treating sewage.
„	2446	William Alexander Lyttle -	Treating sewage.
„	2450	Henry Young Darracott Scott.	Recovering ammonia for sewage.
„	2461	William Spence - -	Treating sewage.
„	2567	Feorge Willett, Robert James Harris, and James Lund.	Filtering sewage.
„	2676	James Alexander Manning -	Dry closets, &c.
„	3122	Bridge Baron Standen -	Treating excrement.
„	3199	John Howard Kidd -	Treating sewage for manufacturing manure.
„	3225	James Mc. Intyre - -	Purifying sewage waters.
„	3326	Francis Thomas Bond -	Treating liquid refuse, &c.
„	3384	Francois Alcidi Bonnefin -	Treating excrementa.
„	3459	Samuel Hallsworth and Richard Bailes.	Treating and clarifying sewage, &c.
„	3751	George Mackay - -	Purifying liquids.
„	3784	Burton Henry Valle -	Treating sewage.
„	4158	Rupert Goodall - -	Clarifying impure water or sewage.
„	4247	James Conyers Morrell -	Sewer pipes, &c.
„	4305	Henry Young Darracott Scott.	Treatment of sewage.

Date.	Number of Patent.	Name of Patentee.	Purpose of Patent.
1875	150	George Rydill - -	Purifying sewage, &c.
"	214	John Box, Edouard Aubertin, Leopold Boblique, and Hypolite Leplay.	Disinfection of sewage, &c.
"	373	Henry Young Darracott Scott.	Manures.
"	399	George Rydill - -	Treating sewage.
"	573	Samuel Hallsworth and Richard Bailles.	Clarifying sewage, &c.
"	1195	Francis George Whitwharn	Treating excreta.
"	1216	William Edward Newton -	Treating fecal matters, &c.
"	1335	William Morgan-Brown -	Treating sewage.
"	1625	Thomas Pape - -	Filtering and deodorizing sewage.
"	1759	John Yale - - -	Barge for receiving and conveying sewage.
"	1845	Mark French Anderson -	Treating sewage.
"	1954	Joseph James Coleman -	Treating sewage.
"	1972	Daniel Wilks - -	Collecting and treating sewage.
"	2358	James Odams and Robert Blackburn.	Apparatus for treating sewage.
"	2557	Frederick William Granham	Filters.
"	2621	David Gill - - -	Deodorizing sewer gas.
"	2675	John Hanson - -	Treating sewage.
"	2798	Joseph Robinson - -	Discharge of sewage from towns.
"	2829	Thomas Stevens - -	Treating sewage.
"	3162	Alexander Melville Clark -	Treating sewage.

APPENDIX No. VII.

ABSTRACTS from the REPORTS of ROYAL COMMISSION, and others, who have inquired into the best Modes of DISTRIBUTING the SEWAGE of TOWNS and of applying it to beneficial and profitable Uses.

The following extracts are taken from published reports which are now out of print, and which consequently cannot be made generally available. On referring to them, it will be seen that there are detailed statements, as also conclusions and recommendations, which have as much value now as at the time they were made. Our more recent examinations of towns, sewage farms, and the several modes of treating sewage, confirm the conclusions almost to the letter. We therefore point to these extracts as justifying our own conclusions.

EXTRACTS from the REPORTS of the ROYAL COMMISSION.

PRECIPITATION of the SOLID MATTER of SEWAGE.

Of the different processes that have been proposed for the precipitation of sewage, that by lime is the simplest. It is also the only one that has hitherto been put into practical operation to any considerable extent, and we may be therefore allowed, without disparagement to other methods, to select it as a type for illustration of the whole.

The use of lime to separate the solid matters of sewage is founded on the following circumstances. Sewage of itself, from the slimy, glutinous character of the matter floating in it, and from the specific weight of that matter being so nearly the same with water, will only separate very imperfectly, and after a length of time, into a clear liquid and a solid deposit.

The addition of lime, however, by the chemical changes which it induces, but which we need not here describe, causes a separation of the solid suspended matter in a state of flocculence, in the same way that white of egg clears coffee or isinglass fines beer.

The result is that the sewage rapidly changes its character, separating readily into a deposit, which falls to the bottom, leaving a clear liquid. This is essentially the process that is carried on at Leicester, Tottenham, and other places, the two named being the most important. The clear liquid after subsidence of the solid matter is considered comparatively pure and unobjectionable, and is allowed to flow into the rivers. The solid is drained, as far as possible, and finally dried, and then offered for sale as manure.

We may state our belief that, as far as present knowledge goes, that is, up to 1858, this very simple process offers as much prospect of commercial advantage in respect to the manufacture of a solid manure from sewage as any patent process that has been proposed up to this date.

But with reference to the prospect of obtaining any very large profit from the treatment of sewage, we see no reason to dissent from the view that has been individually held and promulgated by several of our members, namely, that neither the lime process nor any other existing method of precipitating sewage is likely to be commercially advantageous to those who engage in it. We consider that this is, however, not the light in which the matter should be viewed. The great problem is to get rid of sewage advantageously to agriculture, if it may be; if not, at the least expense to the community at large.

Throughout the discussions that have hitherto occurred upon this question, the real issue has been left comparatively in abeyance. The

primary consideration is not whether sewage can be made serviceable to agriculture, but whether or not there exists any method which, consistently with a fair expenditure of money, falling on those who ought in justice to bear it, will practically rid us of the nuisance and danger attendant upon town sewage.

The object must be accomplished, and the question is, simply, how its accomplishment can most satisfactorily be attained. All other considerations are secondary to this. The process of precipitation by lime, as carried out at Tottenham, and on a larger scale at Leicester, is satisfactory up to a certain point. The solid matter of the sewage is effectually separated, and a clear and comparatively innocuous liquid is run off. We shall presently consider the objections that have been urged against this liquid, but we wish now to point out that any nuisance which is chargeable to works such as those at Leicester and Tottenham is due, not to the act of precipitation, but to the process employed for drying the solid matter into a condition fit for sale. At both the establishments in question the sewage is received and treated in closed or covered tanks, and, as the lime considerably diminishes the smell of the sewage, the whole operation can be carried on, and the clear liquid run off, without offence. But the solid deposit which settles down in the form of a thick sludge must be removed, and must in some way be dried. This part of the operation is very difficult; it requires much space, and the value of the product is too small to allow of the drying being entirely effected by artificial heat. Consequently, both at Tottenham and Leicester, we found great pits and mounds of this sludge undergoing a gradual process of draining and drying in the open air; and it is to these accumulations of the precipitated matter of sewage, exposed to the sun and other agencies, that the offensive smells must be attributed, which sometimes, but not always, are perceptible from the works.

As an inexpensive means of avoiding nuisance, we may here advert to the simple process adopted by the Local Board of Health at Cheltenham for separating and disposing of the solid matters of sewage in conjunction with the use of lime, which has been attended with considerable success. This method seems likely to be made available in many other places with advantage.

The chief portion of the solid matter is separated in tanks by deposition and a coarse filtration or straining process, the liquid flowing off is then treated with lime in order to diminish the smell and to precipitate the finer particles in suspension in the water before it is allowed to flow into the stream. The deposit or sludge first obtained is mixed with ashes and scavenger's refuse of the town, and thus a solid manure is formed which has been bought by the farmers in the neighbourhood at 2*s.* 6*d.* per cubit yard. A charge of 3*s.* 6*d.* per cubic yard would pay all working expenses and interest on the outlay, and it is thought that this price might be obtained for it; but one most desirable and necessary thing is to have a regular and speedy removal from the ground.

With regard to the liquid which results from the operation of liming sewage, its frequent examination by different chemists has proved, what would in fact have been anticipated, that it contains a considerable quantity of dissolved matter of a vegetable and animal origin which the lime is incapable of separating; a certain amount of smell also remains, although by no means the same in kind or degree as the crude sewage.

In the report of Dr. Hoffman and Mr. Witt, addressed to the referees on metropolitan drainage, the subject of these precipitating processes has been discussed at some length. These gentlemen have arrived at the conclusion that, inasmuch as a quantity of "putrescible" matter is left in

the liquid resulting from liming the sewage, and that this liquid when kept during warm weather is liable to become a second time offensive to the senses and consequently dangerous to health, such process is not admissible in the case of the metropolis. But we submit that the question is not whether, in the abstract, sewage after treatment with lime contains vegetable and animal matters in solution, and is liable to further putrefaction, but whether such treatment so far destroys the noxious character of sewage that practically it may be thrown into rivers without danger.

Without going so far as to say that the precipitation by lime is a perfect process, or that it can in all cases be adopted, we feel satisfied that it does to a great extent fulfil the purpose for which it is employed, so far, at least, as the purification of rivers is concerned.

By far the largest amount of nuisance and danger arising from the pollution of rivers by sewage is due to the solid suspended matters which give off noxious effluvia throughout the period of their decomposition. This is especially the case in our tidal rivers, where these deposits form shoals and cover the banks, and at low water offer a vast surface of offensive matter for the contamination of the air. The lime process does effectually remove this gross solid suspended matter, and in so far accomplishes a great and manifest good. It also destroys the immediate influence of the noxious gases in sewage, and although it may, in the abstract, be open to the objection of still leaving matter capable of further putrefaction in the liquid, we are of opinion that wherever this liquid is thrown into a body of water considerably larger than itself (not less than 20 times the volume of the clarified sewage) no evil results will practically be experienced.

Our conclusion, then, is, that in the absence of means for a direct application of sewage to land, the methods of precipitation at command by lime do actually offer remedial measures of a satisfactory character. It remains to consider whether these remedial measures are within the fair limits to which a town population may be taxed for the suppression of the sewage nuisance.

We have already stated our belief that unless some new process of greater efficiency should be discovered, the formation of a solid manure from sewage will not be remunerative; that is to say, that the amount realized by the sale of the manure will fall short of the cost of its production. Neither is this to be considered as a condition dependent on the want of appreciation of the manure, which time and better information on the part of the consumer will remove; on the contrary, the tendency has been hitherto to put the price above the value which a sound acquaintance with the nature of manures would attach to it. It is even questionable whether, in some instances, any money at all would be given for this deposit, and in considering the practicability of carrying into effect plans for the precipitation of sewage we must be prepared for this eventuality.

It will therefore be placing the matter in a necessary, although the least favourable, light, if we consider that the manure when made possesses only so much value as to induce farmers to cart it away without paying for it. It may be desirable, however, that we should here advert to a plan by which the expenses attendant on these precipitating processes would be very materially reduced, and the necessity for works for this purpose in the vicinity of towns, and the possible nuisance or fear of nuisance to which they might give rise, would be entirely obviated. This plan is to limit the process to the precipitation of sewage, and after allowing the clear liquid to run off, to pump the sludge or mixture of deposited matter and water directly on to the fields through pipes.

Remarks.—This process of pumping sewage-sludge direct from the tanks where it is deposited to the land is practised at Birmingham. The sludge is spread over land to the extent of one statute acre per week, and is trenched or dug in at a cost of 14*l.* 10*s.* per acre. In this position the water absorbs or evaporates, and leaves the dried earthy matter in the soil. After the interval of a year the land can be used for farming purposes. The sludge as pumped contains about 90 per cent. of water, which dries away in about 12 months' time.

It has already been stated that the chief source of nuisance, or liability to nuisance, in such works consists in the necessity for drying the sludge, and a very large portion of the original outlay for works and the area required for such works, and of the daily expenses, is involved in this part of the operation. By the plan above mentioned all these difficulties would be materially reduced, the works would be confined to the precipitating tanks and the engine for pumping, and neither the sewage nor the deposit would see the light of day before the clarified water was discharged in a comparatively innocuous state into the rivers, and the sludge was deposited on the fields.

It has been calculated that the quantity of sludge to be pumped would not exceed 5 per cent. of the whole sewage, so that the cost of applying it would be small in comparison with that of distributing the whole sewage on the land.

Remarks.—The Commissioners did not apparently anticipate the cost of digging in the sludge at 14*l.* 10*s.* per acre, and the loss of at least one year's rent of the land.

We have already stated that the processes for separating the solid matter do not realize the agricultural value of the sewage. It has long been understood that at least four fifths of the substances valuable in relation to vegetation pass away with the water; the solid matter, therefore, which in this plan would be pumped on the land, would not fertilize so large an area as the whole sewage; but in relation to the necessary disposal of sewage, which it is our duty to keep steadily in view, this circumstance would offer some advantages, inasmuch as it would in many cases be much easier for town authorities to find the smaller area of land upon which it might be applied than that extensive space which the whole sewage would require. Other modifications in carrying out this system will readily present themselves.

The two methods for the disposal of sewage, that is to say, by direct application to land, or by precipitating processes, have been, perhaps, sufficiently considered. It is almost unnecessary to add that they can be worked conjointly, and in some cases such a plan would be attended with advantage. Thus, for instance, where opportunities occurred for the disposal of a part of the sewage for direct application, though the whole could not immediately be so got rid of, the remainder might be treated by methods of precipitation.

The erection of works for the latter purpose would obviate the present nuisance, and give time for that change of opinion which will ultimately cause the sewage to be sought after by agriculturists.

Moreover, in many cases the previous separation of the solid matter may increase the facilities for liquid application, allowing of the use of large quantities by open irrigation on a limited area without the risk of nuisance.

Remarks.—The land filtering process will enable large volumes of clarified sewage to be filtered on small areas, 2,000 persons to one acre.

It remains now only to revert to one point in relation to the character of the liquid after these precipitations of sewage have been effected.

It has been already mentioned that objections have been taken to lime

and other similar processes, on the score that the liquid is liable to become again putrid. We have stated that we believe this circumstance to be practically unimportant, but, as it is a wise policy in all cases to avoid even the occasion of offence, it is very desirable that even this objection should be overcome. If, after the separation of the solid matters by lime or other precipitants, any further treatment of the clear liquid would place it in a condition in which ulterior change involving the production of offensive and noxious smells would be impossible, the problem, both in a theoretical and practical sense, would be most completely solved.

We are of opinion that the accomplishment of this object is quite within the means of chemical science, and we feel ourselves justified in expressing this conviction from the results of experiments which have already been made in presence of some members of the Commission, although our investigation of this point is not yet complete.

From the whole of our inquiry we have arrived at the following conclusions:—

Preliminary Report, March 1858.

Conclusions.

1st. That the increasing pollution of the rivers and streams of the country is an evil of national importance, which urgently demands the application of remedial measures; that the discharge of sewage and other noxious refuse of factories into rivers is a source of nuisance and danger to health; that it acts injuriously not only on the locality where it occurs, but also on the population of the districts through which the polluted rivers flow; that it poisons the water, which in many cases forms the sole supply of the population for all purposes; that it destroys fish; and, generally, that it impairs the value and the natural advantages derived from rivers and streams of water.

2nd. That this evil has largely increased with the growing cleanliness and internal improvements of towns as regards water-supply and drainage; that its increase will continue to be in direct proportion to such improvements, and that as these improvements are yet very partial, the nuisance of sewage, already very sensibly felt, is extremely slight as compared to what it will become when sewerage and drainage works have been carried into full effect.

3rd. That, in many towns, measures for improved water-supply and sewerage are retarded from the difficulties of disposing of the increased sewage which would result from them; that the law which regulates the rights of outfall is in an anomalous and undefined condition; that judicial decisions of a conflicting character have been arrived at in different instances; and, that consequently the authorities of towns have constantly before them the fear of harassing litigation.

4th. That the methods which have been adopted with the view of dealing with sewage are of two kinds: the one being the application of the whole sewage in its crude state to land; and the other, that of treating it by chemical processes, to separate its most offensive portions; that the direct application of sewage to land favourably situated, if judiciously carried out, and confined to a suitable area, is profitable to persons so employing it; that where the conditions are unfavourable, a small payment on the part of the local authorities will restore the balance.

5th. That this method of sewage application, conducted with moderate care, is not productive of nuisance or injury to health.

6th. That when circumstances prevent the disposal of crude sewage

by direct application to land, the processes of precipitation will greatly ameliorate and practically obviate the evils of sewage-outfalls, where there is the sea, or a large river for the discharge of the liquid ; that such methods of treating sewage do not retain more than a comparatively small portion of the fertilising matter; and, that although in some cases the sale of the manure may repay a portion of the cost of production, solid manure manufacture is not likely to be successful commercially.

7th. That, considered merely as the means of mitigating a nuisance, these precipitating processes are satisfactory ; that the cost of them in any case is such as town populations may reasonably be called upon to meet ; that the necessary works need not, if properly conducted, be a source of nuisance, and that, by modifications of the existing methods, even the slightest risk of nuisance may be entirely obviated.

8th. That the employment of the one or other method of disposing of sewage, or of both conjoined, must depend upon locality, levels, markets, and a variety of other circumstances, and that the case of each town must be considered upon its own peculiarities.

9th. That there is good ground for believing that the methods yet proposed for dealing with sewage are not the best that can be devised, and that further investigation will probably result in the discovery of processes more thoroughly equal to the suppression of nuisance, and at the same time calculated to give more valuable products.

10. That the magnitude of a town presents no real difficulty to the effectual treatment of its sewage, provided it be considered as a collection of smaller towns.

As, however, the conditions under which the evil may be best removed will differ greatly in different localities, we think it would be desirable, before any legislation takes place on this subject, that investigation should be made into the state of the outfalls of different classes of towns, and of the condition of rivers in populous districts, with the view to advise as to the general legislative measures that might safely be adopted.

Westminster, 26th March 1858.

Second Report, 1861.

Conclusions.

We submit the following conclusions as the result of these our further investigations :—

1. That the pollution of the rivers of the country is so great and general as to have become a national evil.

2. That this pollution has progressively increased in recent years, is still rapidly increasing, and, unless arrested, must necessarily continue to do so in proportion to the increase of population, the progress of town sewering and house drainage, and the extension of manufactures.

3. That although one of the chief causes of this pollution is the practice of discharging crude sewage, as it comes from towns, into the nearest rivers or watercourses, thus converting them into sewers, yet, the pollution from this cause is by no means confined to towns which have adopted systematic measures for improved sewerage. Nor is the amount of pollution in proportion exclusively to the completeness of such works ; for, in many of the towns in which the bulk of the foul refuse is still retained in cesspools and middens, the neighbouring rivers are in a highly offensive and noxious condition,—even where the cesspool

system is maintained on the alleged ground of preserving the local rivers from contamination.

4. That besides the pollution of rivers by the discharge of sewage into them, they are in general made the common and ready receptacles of an immense amount of offensive matter from factories, dye-works, gasworks, iron foundries, mills and other establishments, while cinder-heaps and masses of rubbish of every description that cover their banks, and the large stones and other refuse that obstruct the beds, testify to the general neglect and ill-usage of rivers.

5. That by far the greater part of the solid matter which is held in suspension in water is readily deposited in rivers, covering the banks with mud, permanently raising the beds, gradually destroying the scouring power of the water, and partially silting such rivers up ; and that in some instances these deposits have accumulated to such an extent as to impede navigation, to render the surrounding country subject to floods, and to entail a vast expense in periodic cleansing.

6. That however the appearance of the water may be improved after these deposits have taken place, yet the deposited matters, lying in the bed of the current, are under conditions favourable for putrefaction. And when the foul mud is disturbed by the prevalence of rain, and during floods, it sends forth its effluvia amidst the populations which are near, and even in the course of the rivers far distant.

7. That this condition of rivers is a public and national nuisance; it interferes with the convenience and comfort of all classes of the people ; it damages various and important interests, as those connected with manufacturing establishments, canals, fisheries, and so on ; it deteriorates property to a large extent; and, as interfering with a main source of water supply, is of serious detriment to the public health.

8. That this state of things has grown up in consequence of the anomaly that while important powers of river conservancy have from time immemorial been conferred on local authorities, while special powers have been vested in Improvement Commissioners and companies for isolated local improvement, for drainage, for navigation, and so on, and while even private water-rights and ownerships in streams have been recognized and conferred, no general jurisdiction whatever has been exercised over the whole waters of the country ; no protection has been accorded to the many great and varied interests connected with rivers.

9. That the only way of restoring rivers to their original purity is to prevent the discharge of foul matters into them, and especially the discharge of sewage and other refuse of large towns ; but that, in various cases where this treatment has been deemed inadmissible, expedients for the purpose of depriving the sewage of its offensive and noxious properties have been brought into practical operation, and have been attended with more or less success.

10. That among those methods of which experience is most satisfactory no one is suited to the circumstances of all towns, some towns presenting much greater difficulties than others ; yet the more this subject has been investigated the more convincing is the evidence that there is no town which might not, with reasonable care and at moderate cost, greatly mitigate existing evils where it may not be practicable wholly to remove them.

11. That, for example, the chief part of the nuisance arising from the discharge of sewage into rivers and streams may be obviated at once by simply arresting the solid matter in suspension in the liquid, particularly in towns of small populations where the sewers discharge into considerable streams of water. In these cases it may be practically sufficient to adopt simple means of deposit, combined with mechanical

appliances for arresting solid matters, and these may be of the most inexpensive character ; in other cases, however, and especially during summer, the addition of chemical agents may be required for the more complete separation of solids, and the deodorising of liquid sewage. But although, by such means as the above, sewage may be rendered inoffensive to smell, we cannot guarantee that, even after the best practicable application of such means, sewage can be allowed to flow into any brooks or rivers without rendering the waters unsafe and improper for drinking.

12. That among deodorizers, the material which up to the present time has been found the best for this purpose is *perchloride of iron*, the only objection to its general use being its comparatively high price; but in many cases the employment of the cheaper material, lime, may suffice.

13. That the value of the solid portions of sewage being small, all attempts at realizing profits from its preparation as manure have signally failed ; but, mixed with ashes, sweepings, and other dry refuse of towns, sale is found for it at 2*s*. or 3*s*. per ton, which is sufficient to pay a proportion of the necessary working expenses of mixing.

14. That the cost of the operation has in various instances ranged from ½*d*. to 3*d*. per head of the populalion per annum, including interest on the outlay for works; there can therefore be no difficulty on the ground of expense in requiring the adoption of adequate means for a removal of nuisance in every case in which injury or inconvience is shown to arise.

15. That the most beneficial and most profitable method of disposing of sewage, where circumstances will admit of this use of it, is by direct application in the liquid form to land ; where such applications can only be conveniently effected near habitations, it may be desirable to employ some deodorizing agent; but usually, if proper arrangements are made for conveying sewage on the land, this expense need not be incurred.

There is reason to hope that trials and experiments instituted by the Commission, and still in progress, in relation to the irrigation of land with sewage, will remove some doubts and difficulties which have hitherto prevailed in retarding a more general adoption of this desirable mode of disposing of and utilising the sewage of towns.

Recommendation.

Having now fully stated our conclusions as to the means of disposing of the sewage of towns, and shown that the remedies for the evils which are experienced, although various, are both practicable and economical, we beg to repeat our conviction that the only security for a general and continued employment of such means will be the establishment of responsible conservancies throughout the country, armed with adequate powers for prventing damage and for effecting improvements. We believe that these powers would be best vested in independent local authorities, such as the present Commissioners of Sewers ; acting under certain Government regulations in respect to borrowing money, and other matters. Our inquiry, however, has of necessity been of too imperfect a character to enable us to set forth for consideration any decided measures in detail on so large and important a question. There are many subjects to be inquired into, and vast interests to be considered, which are beyond our present power or our province to enter upon. We can only respectfully but earnestly recommend that such inquiries should

be instituted into the various points bearing on the subject, so that measures may be submitted which will enable Parliament to deal with the existing evils in a way most conducive to public interests.

Whitehall, August 1861.

Third Report of the Royal Commission.

Conclusions.

To the Lords Commissioners of Her Majesty's Treasury.

May it please Your Lordships, March 1865.

We, the undersigned, whom Her Majesty's Commission, bearing date 5th January 1857, appointed to inquire into the best mode of distributing the sewage of towns, and applying it to beneficial and profitable uses, have now again, according to our instructions, the honour of reporting to your Lordships our further progress in the matter committed to us for inquiry.

Since the date of our last Report (August 1861) we have, through a committee of our number consisting of Mr. Lawes and Professor Way, continued at Rugby the experiments which were undertaken in 1861 on the application of sewage to land. The report of that committee, which we append, contains the results for the three years 1862–4.

Your Lordships will observe that these experiments have not been confined to the application of sewage in different quantities to land, but have extended to the consumption by cattle of the produce so obtained, and to the production of meat and milk, and have been accompanied by a careful record of the quantities and market value of the products, and by numerous analysis of the sewage before and after irrigation, as also of the grass and of the milk.

It appears to us that these experiments have solved many of the difficulties which have hitherto attached to the question of the agricultural application of sewage, and that they leave no reasonable doubt of the practicability and advantage of so employing the sewage of towns.

We have also continued to give our best attention to all kindred experiments and inquiries which have been going on elsewhere.

As the results of our labours, extending over eight years, we have confidence in submitting to your Lordships the following conclusions:—

1. The right of way to dispose of town sewage is to apply it continuously to land, and it is only by such application that the pollution of rivers can be avoided.
2. The financial results of a continuous application of sewage to land differ under different local circumstances; first, because in some places irrigation can be effected by gravity, while in other places more or less pumping must be employed; secondly, because heavy soils (which in given localities may alone be available for the purpose) are less fit than light soils for continuous irrigation by sewage.
3. Where local circumstances are favourable, and undue expenditure is avoided, towns may derive profit, more or less considerable, from applying their sewage in agriculture. Under opposite circumstances, there may not be a balance of profit; but even in such cases a rate in aid, required to cover any loss, needs not be of large amount.

Finally, on the basis of the above conclusions, we further beg leave

to express to your Lordships that, in our judgment, the following two principles are established for legislative application:—

First, that wherever rivers are polluted by a discharge of town sewage into them, the towns may reasonably be required to desist from causing that public nuisance:

Second, that where town populations are injured or endangered in health by a retention of cesspool matter among them, the towns may reasonably be required to provide a system of sewers for its removal.

And should the law, as it stands, be found insufficient to enable towns to take land for sewage application, it would, in our opinion, be expedient that the Legislature should give them powers for that purpose.

Whitehall, 1865.

EXTRACT from a REPORT by HENRY AUSTIN, Esq., C.E., prepared for the ROYAL SEWAGE COMMISSION.

Mr. Henry Austin, Chief Inspector of the Board of Health, was also a member of the Royal Sewage Commission, and was requested to prepare a Report for the Commission, of which these are the conclusions:—

As the result of my inquiries, and of the best attention which I have been enabled to afford to this important subject, I beg to submit the following conclusions:—

CONCLUSIONS.

1. That although from the earliest agitation of the question of sanitary reform, and of the complete drainage of towns, the mischief from pollution of rivers on the one hand, and the waste of valuable manure on the other, by the direct discharge of the sewage, was insisted upon, no conception was at any time formed of the extent of the evil which now so imperatively calls for remedy.

2. That although the means of remedy by deodorization appear to be as yet but imperfectly understood, and demand further investigation, various processes have for a long time been in more or less successful use for this purpose. That the employment of some of these, known to be destructive of the fertilizing power of sewage, would involve expense without any return, and although such expense, if unavoidable, should unhesitatingly be incurred to avoid any permanent danger to the population, it appears that other deodorizing materials are not destructive of that fertilizing power. That it is most important, therefore, to determine whether the fertilizing elements in the refuse are presented in such form as to be practically available for agriculture, either in the solid state or in the liquid form, so as to avoid the injurious consequences and enormous waste of throwing away the sewage.

3. That the nature and value of the chemical constituents of the fœcal matter in sewage having long been known to physiologists and chemists, and admitted to contain all the elements necessary for the food of plants, the recent discussions as to its practical value for agriculture have not arisen from any doubts on that point, but from the uncertainty whether, being diluted in the large bodies of water employed for the drainage of towns, that value is realizable.

4. That chemical research has not yet arrived at any satisfactory

method of economically arresting from solution the fertilizing ingredients in sewage, while the analyses of solid sewage manures, manufactured under various patents, show that, although for the most part possessing a certain low value, they do not justify the high prices at which they have been offered to the public; nor does there appear to be evidence of any agricultural results derived from their use which will support such a view of their value.

5. That the manufacture from excrement of a dry portable manure, as practised at Paris, although realising results of greater value, is applicable only where the cesspool system prevails, and leads to an aggravation of the nuisance of that system, which due regard for the public health would not tolerate.

6. That the separate system of drainage, frequently proposed as a solution of the sanitary and agricultural difficulties of the sewage question, would increase immensely the cost of drainage works, would add to the sources of danger to the public health, and would tend to a waste of fertilizing power.

7. That the practical experience obtained during many years at Edinburgh and Milan has shown the great value of sewer-water on grass lands, although applied in a state of great dilution; while valuable experiments have shown the power of soils to remove from solution, and retain for vegetation, the fertilizing elements.

8. That notwithstanding the enormous quantities of sewage-water which have been applied to the land at Edinburgh, the produce is said to be always in corresponding ratio to such quantity, and that the limits of quantity to be applied, and of produce to be realised, have not yet been ascertained.

9. That the precise value of the manure in a given quantity of sewer-water may be readily determined, and, therefore, that the corresponding quantity of water which must be applied to convey a certain required quantity of such manuring elements on to the land may be at any time known.

10. That although such immense agricultural results have been obtained from irrigation with sewage-water at Edinburgh, the method employed has given rise to much complaint of nuisance. That this arises for the most part from foul deposits in wide ditches, and from the large evaporating surfaces of the sewage constantly exposed in the channels of irrigation.

11. That all such sources of nuisance and danger are preventible, and should not be tolerated. That no ditches should be used, and that the sewage should be exposed only during the act of irrigation of each portion of the land, when it would be immediately absorbed and deodorized by the soil.

12. That in order to avoid all further risk of injury to health, whether from discharge of the sewage into the rivers and streams, or from its application to the land, it appears desirable that the solid matter should in every case be separated from the liquid sewage at the outfall, and that a cheap, portable manure should be manufactured therefrom for use in the immediate neighbourhood, as practised at Cheltenham. That it should be mixed with the ashes of the town, or such other deodorizing material as may be most suitable for application to the surrounding land, and prepared, if desirable, with other manuring ingredients for particular crops.

13. That it appears probable that such operation will, in most places, pay its own expenses; but that as some such measure is absolutely necessary for the public health, even though involving some expense, it

should be the duty of local boards and other governing bodies to carry it out, just as much as arrangements devolving upon them for removal of dust or other refuse from the town. It should form, in fact, part of such service, and might be combined in the same contract.

14. That the liquid portion of the sewage, thus cleared of its solid matter, but still retaining its chief value as manure, might then be applied with benefit to the neighbouring lands in any quantity; but that all land upon which this method of application of the sewage is practised should, if not naturally porous, be artificially drained, as the liquid, if allowed to become stagnant, would, as in common irrigation, be likely to engender disease in the neighbouring inhabitants or in cattle exposed to its influence.

15. That the distribution of manures in the liquid state by the hose and jet, from a system of underground pipes on the land, has been found, by the experience of several years upon farms in England and Scotland, most advantageous, and that the outlay for such works is considered by eminent agriculturists who have had experience of their benefits, as a very profitable outlay, irrespective altogether of the question of sewage distribution.

16. That although the adoption of the the same system at Rugby and other places for the distribution of liquid sewage has been found decidedly successful, the great Edinburgh results are not attainable by this method, unless conjoined with more ample and ready means for getting much larger quantities of sewage on a given area, in less time, and with less labour and expense than can be done with the hose.

17. That upon grass lands, for which the application is best adapted, these larger quantities of the liquid sewage, deprived of its grosser particles, may be economically distributed, especially upon the lower levels, by a combination of the underground pipe system with the subsidiary open irrigation by small contour gutters, practised by Mr. Bickford.

18. That this work, being of a commercial or speculative nature, and not so much required for the safety of the public health, would fall rather within the province of local companies or proprietors than of the local authorities, and to those parties all facilities should be granted for carrying it out.

19. That the solid sewage manure, prepared and deodorized as above proposed, may be anywhere used, and any quantity of the liquid applied on absorbent or properly drained land, without any risk of injury to health, and without any of the offensiveness constantly experienced from farmyard and other solid manures applied as top dressings.

20. That in any neighbourhoods, however, where no opportunity exists for this beneficial irrigation, the liquid sewage, before being discharged into rivers or streams, should, after separation of the solid matter, be treated with lime or other deodorizing and precipitating agents; a duty which should devolve upon the Local Board or other governing body, as a precaution in which the public health is materially concerned.

Lastly, that it is an object of immense public concern that the poisonous accumulations of our towns, now fast becoming the sources of pollution of our rivers and streams, should without delay be rendered powerless for further mischief, and applied as nature's law demands for reproductive uses. That by this means the greatest sanitary problem will be solved, and the greatest advancement of agricultural prosperity secured.

In drawing this report to a close, I venture to express a hope that the attention I have been enabled to give to the subject may have added some little to our information; but impressed with its great importance

and its difficulties, extending as it does into so many branches of inquiry, I feel strongly my own inability to do justice to it. It is a subject of study not for engineers alone, but for agriculturists, physiologists, and chemists of the highest attainments and experience.

I have, &c.
Henry Austin,
Chief Superintending Inspector.

Whitehall, March 1857.

Conclusions from the First and Second Reports of the Select Committee on the Sewage of Towns. Dated 10th April 1862.

Analysis of Evidence.

1. The evidence proves that sewage contains the elements of every crop which is grown.

2. That as compared with solid manure there are advantages in the application of sewage manure to land.

3. The evidence proves that town sewage contains a large amount of heat, which in itself is beneficial in stimulating vegetation.

4. The evidence also proves that the water alone of sewage is of great benefit for agricultural purposes.

5. The evidence further proves that one ton (224 gallons) of average town sewage contains an amount of manure which, if extracted and dried, would be worth a little over 2*d.*, taking Peruvian guano (at 11*l.* per ton) as the standard.

6. A judicious use of town sewage permanently improves land.

7. Sewage may be applied to common grass, Italian rye-grass, and also to roots and grain crops, with great advantage, dressings with sewage hastening vegetation.

8. Sewage-grown grass has a great effect in increasing the quantity and richness of the milk of cows, as well as improving the condition of the cattle, which prefer sewaged grass to all others.

9. The earth possesses the power of absorbing from sewage all the manure which it contains, if the dressings in volume are proportioned to the depth and quality of the soil.

10. Those who use sewage should have full control over it, that they may apply it when and in what quantities they may require it.

11. Heavy dressings of sewage (8,000 to 9,000 tons per acre) are wasteful; less dressings (500 to 2,000 tons per acre) when more carefully applied, produce better results. The enormous dressings recommended by some witnesses would be agriculturally useless, as the sewage would flow over and off the surface unchanged.

12. When the sewage of our cities, towns, and villages is utilized to the best advantage over suitable areas, little or no imported or manufactured manures would be required in such districts.

13. Sewage may be applied with advantage to every description of soil which is naturally or artificially drained.

14. The most profitable returns, as in the case of all other manures, will be obtained when sewage is judiciously applied to the best class of soils.

15. Sewage may be advantageously applied to land throughout the entire year.

16. Some matters used in manufactures which enter town sewers,

such as waste acids, would be in themselves injurious if applied to vegetation; but bearing as they do so small a proportion to the entire volume of sewage into which they are turned, they are rendered harmless.

17. Fresh sewage at the outfall of the sewers, even in the hottest weather, is very slightly offensive; and if applied to the land in this state, in such dressings as can at once be absorbed by the earth, fear of nuisance need not be felt, as the soil possesses the power to deodorize and separate from liquids all the manure which they contain.

18. Large dressings and an over-taxed soil may pollute surface streams, subsoils, and shallow wells.

19. Solid manure cannot be manufactured from town sewage with commercially profitable results.

Report on the Results of the Society of Arts Conference on Health and Sewage of Towns, June 1876.

Conclusions.

The chairman of the Conference and the Executive Committee, after having carefully considered the information furnished from the various localities as well as the facts brought forward during the Conference, have to submit the following as the conclusions to which such information appears to lead:—

1. In certain localities where land at a reasonable price can be procured with favourable natural gradients, with soil of a suitable quality and in sufficient quantity, a sewage farm, if properly conducted, is apparently the best method of disposing of water-carried sewage. It is essential, however, to bear in mind that a profit should not be looked for by the locality establishing the sewage farm, and only a moderate one by the farmer.
2. With regard to the various processes based upon subsidence, precipitation, or filtration, it is evident that by some of them a sufficiently purified effluent can be produced for discharge without injurious result into water-courses and rivers of sufficient magnitude for its considerable dilution; and that for many towns where land is not readily obtained at a moderate price those particular processes afford the most suitable means of disposing of water-carried sewage. It appears, further, that the sludge, in a manurial point of view, is of low and uncertain commercial value, that the cost of its conversion into a valuable manure will preclude the attainment of any adequate return on the outlay and working expenses connected therewith, and that means must therefore be used for getting rid of it without reference to possible profit.
3. In towns where a water-carried system is employed, a rapid flow, thorough ventilation, a proper connexion of the house drains and pipes with the sewers, and their arrangement and maintenance in an efficient condition, are absolutely essential as regards health; hitherto sufficient precautions have rarely been taken for efficiently ensuring all the foregoing conditions.
4. With regard to the various dry systems where collection at short intervals is properly carried out, the result appears to be satisfactory, but no really profitable application of any one of them appears as yet to have been accomplished.
5. The old midden or privy system, in populous districts, should be discontinued, and prohibited by law.

6. Sufficient information was not brought forward at the Conference to enable the Committee to express an opinion in regard to any of the foreign systems.
7. It was conclusively shown that no one system for disposing of sewage could be adopted for universal use; that different localities require different methods to suit their special peculiarities, and also that, as a rule, no profit can be derived at present from sewage utilization.
8. For health's sake, without consideration of commercial profit, sewage and excreta must be got rid of at any cost.

The Executive Committee, whilst abstaining from submitting any extensive measures, have no hesitation in recommending that the prevention of dangerous effects from sewage gases should receive the immediate attention of the Legislature, and they submit the following resolutions as the basis of petitions to Parliament:—

1. That the protection of public health from typhoid and other diseases demands that an amending Act of Parliament be passed, as soon as possible, to secure that all house drains connected with public sewers in the metropolis and towns having an urban authority should be placed under the inspection and control of local sanitary authorities, who shall be bound to see to the effective construction and due maintenance of all such house drains, pipes, and connexions. Provisions having this object in view already exist in the Act constituting the Commissioners of Sewers in the City of London, in the Metropolis Local Management Act, 1855, and in the Public Health Act, 1875, but practically they seem scarcely sufficient for the purpose.
2. That plans of such drains and connexions be deposited in the charge of the respective local authorities, who shall be bound to exhibit them and supply copies of them to the public on payment of a moderate fee.
3. That the owners of houses be compelled by law to send to the respective local authorities, within a specified time after the passing of the Act, plans of all house drains on an appointed scale.

Signed by—

Members of the Executive Committee.

- The Right Hon. James Stanfield, M.P., Chairman of the Conference.
- Lord Alfred S. Churchill, Chairman of the Council.
- F. A. Abel, F.R.S., President of the Chemical Society.
- Sir Henry Cole, K.C.B.
- Capt. Douglas Galton, R.E., C.B., F.R.S.
- Lieut.-Colonel E. F. Du-Cane, R.E. C.B., Surveyor General of Prisons.

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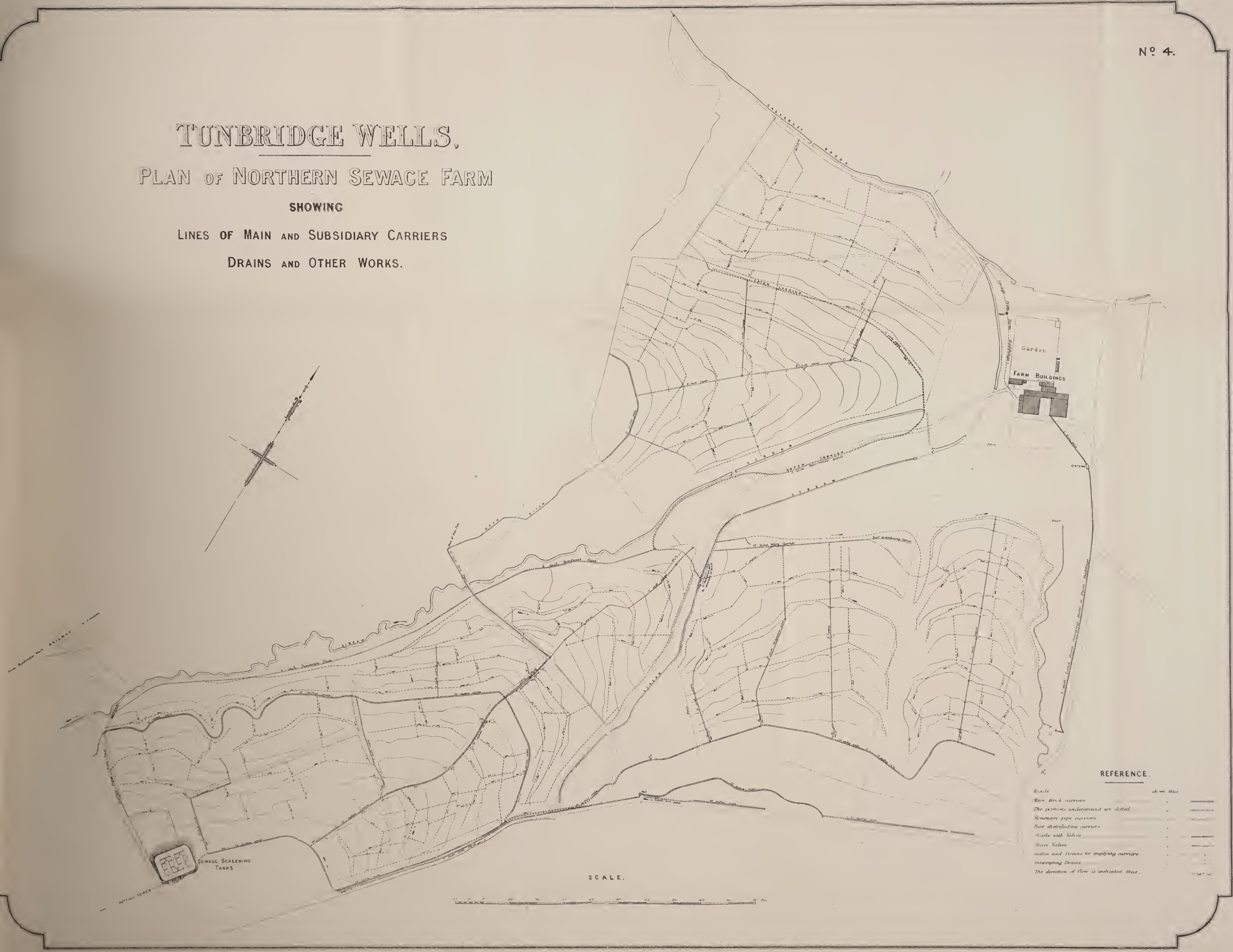
No. 1.

BEDFORD SEWAGE FARM.

N. B. The red lines shew the surface carriers.
Cast-iron mains from the sewage pumps are shewn by blue lines.
The entire farm is free-soil the small volume of outflow of water is at all times bright and pure.

No. 2.
Plan
OF THE
DONCASTER SEWAGE FARM
AT
LONG SANDALL
in the West Riding of the
COUNTY OF YORK.
WEST LANE
CLAY LANE
LITTLE LANE
SHAW LANE
HILLS LANE
RIVER DON
BRICK YARD
THE FARM PREMISES
SAND PIT
FILTERING AREA
PUMPING MAIN
THE TANK
Outfall for Effluent Water
To Barnby upon Don
To Hatfield
To Arnthorpe
From Doncaster
Labourers Cottages
Key Plan shewing the situation of the Sewage Farm with reference to the Town of Doncaster
THE SEWAGE FARM
TOWN OF DONCASTER
Pumping Main 21 dia.
Scale 6 Inches to a Mile.
NOTE. The Main Sewers are shewn Red
NOTE. The Sewage Carriers are shewn in Red and are Glazed Socket Pipes.
The Subsoil Drains are shewn Blue, and the ⟶ indicate the fall
The Levels given are height above mean sea level.
The word 'Outlet' means Outlet from Sewage carriers for irrigation.
SCALE OF CHAINS.


No 3.
PLAN OF THE BARNHURST.
OR
WOLVERHAMPTON SEWAGE FARM.
STAFFORDSHIRE & WORCESTERSHIRE CANAL
Autherley Junction
Outlet
BIRMINGHAM AND LIVERPOOL CANAL
To Oxley Moor
Brook
Outlet
From Wolverhampton
DEPOSIT TANKS AND FILTER BEDS
OPEN CARRIER
From Pendeford
Outlet
COVERED CARRIER
THE BARNHURST
GREAT WESTERN RAILWAY
LITTLE BARNHURST
N B Land drains shewn by blue lines
Pipes for conveying sewage to the upper land shewn by green lines.
Reservoirs coloured pink and numbered 1 2 are low areas, deep drained, to act as Land-filters for storm-waters during heavy rain.
From Shrewsbury
Scale 6 Chains to an Inch.
5 4 3 2 1 0 5 10 15 20 Chains
From Wolverhampton


No. 4.
TUNBRIDGE WELLS,
PLAN OF NORTHERN SEWAGE FARM
SHOWING
LINES OF MAIN AND SUBSIDIARY CARRIERS
DRAINS AND OTHER WORKS.
Garden
FARM BUILDINGS
SEWAGE SCREENING TANKS
SCALE.
REFERENCE.
Roads shown thus
Main Brick carriers
The portions underground are dotted
Stoneware pipe carriers
Turf distributing carriers
Shafts with Valves
Sluice Valves
Gullies and Drains for emptying carriers
Intercepting Drains
The direction of flow is indicated thus

KENDAL SEWAGE.

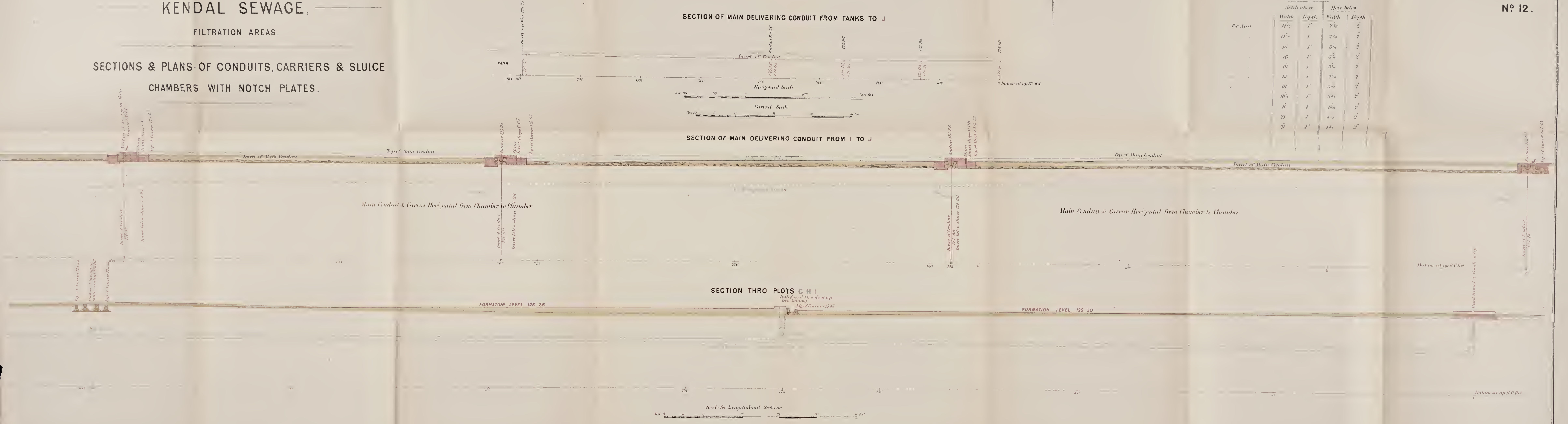
FILTRATION AREAS.

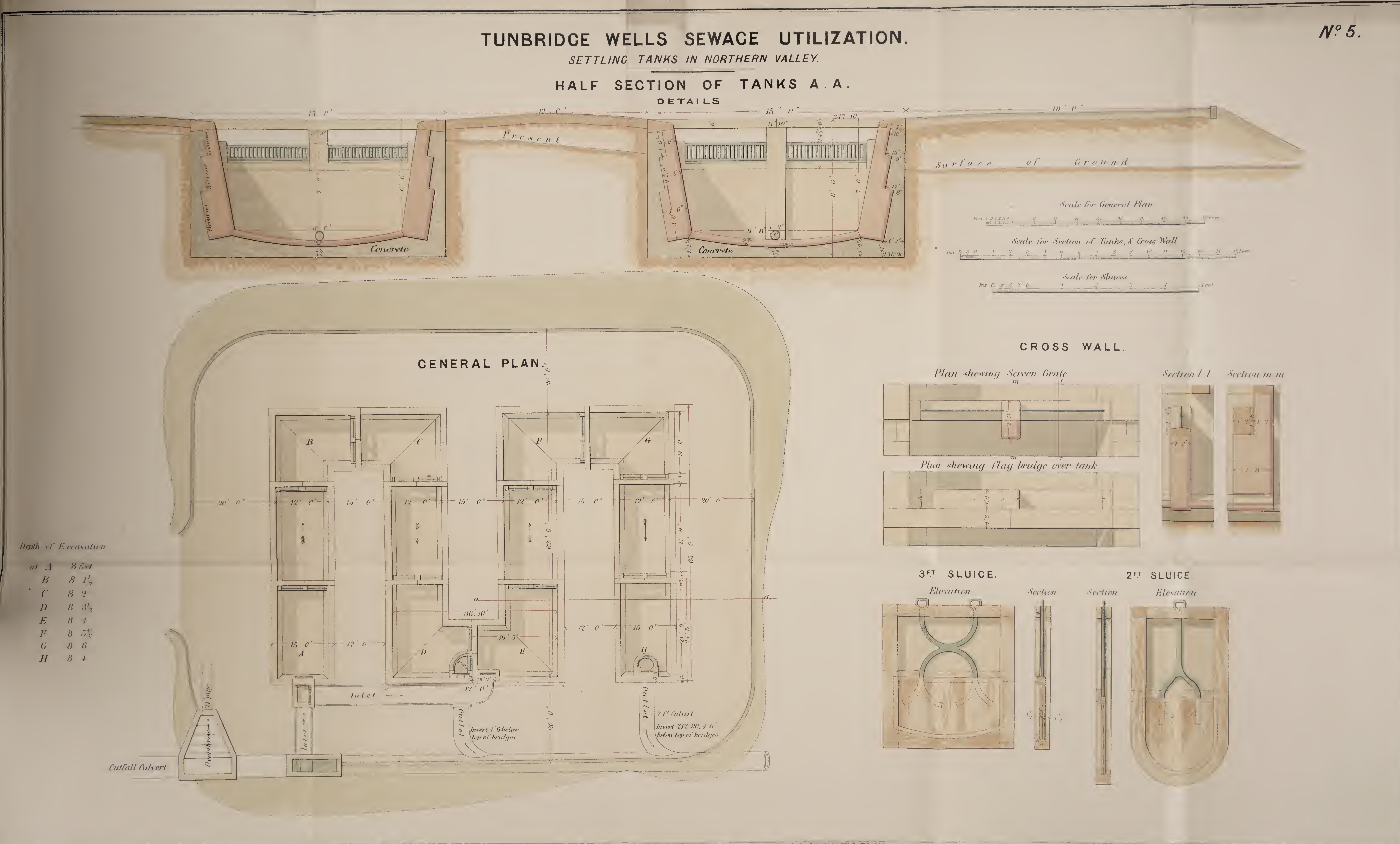
SECTIONS & PLANS OF CONDUITS, CARRIERS & SLUICE CHAMBERS WITH NOTCH PLATES.

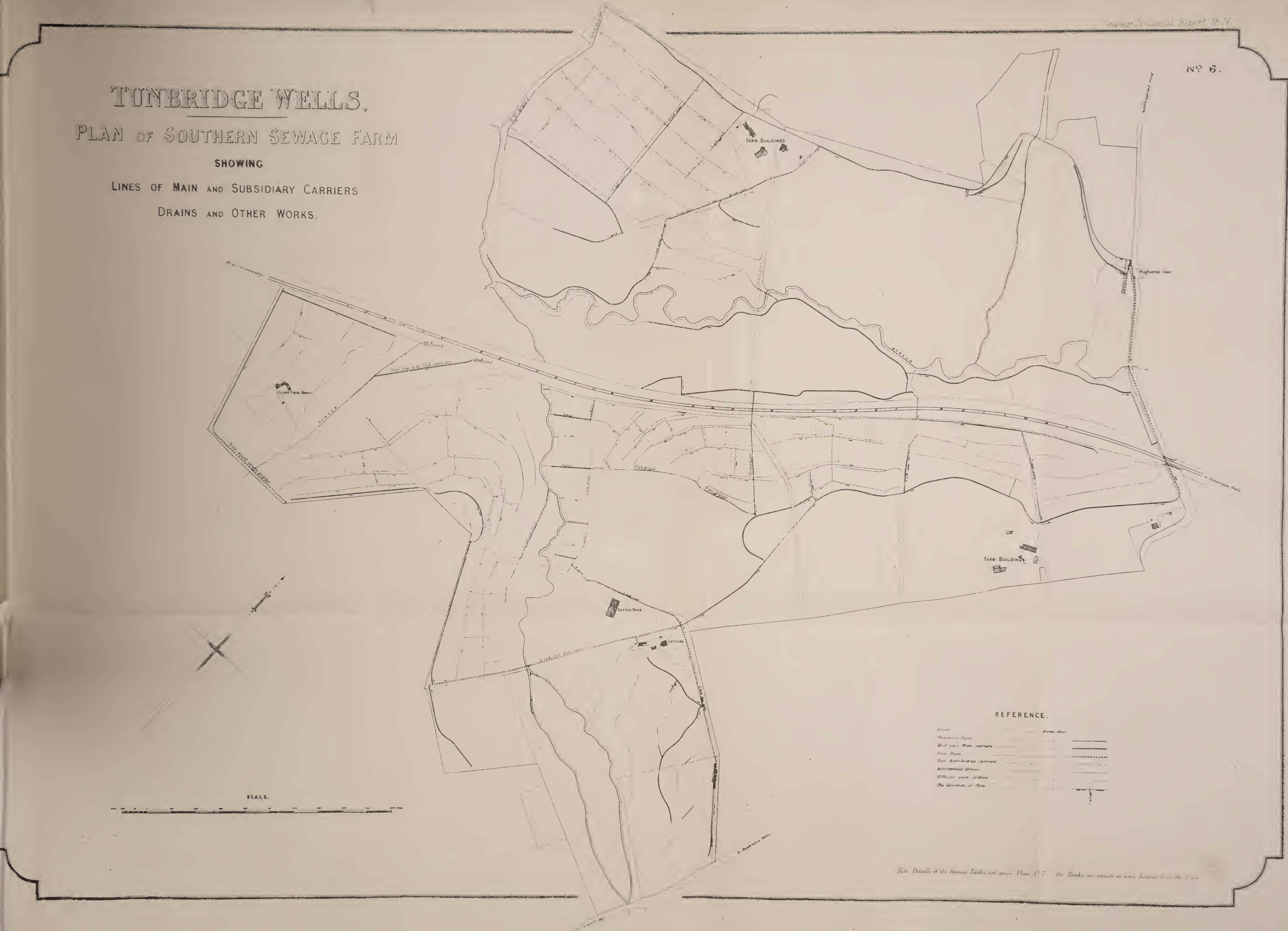
No. 12.

NOTCH PLATES

	Notch above		Hole below	
	Width	Depth	Width	Depth
For Area	11½	1"	2⅞	2"
	11½	1	2⅞	2
	16	1"	3¼	2
	16	1"	3¼	2"
	16	1	3¼	2
	15	1	2⅝	2
	18	1"	[illegible]	2
	18½	1"	[illegible]	2"
	8	1"	1⅝	2"
	21	1	4¼	2
	24	1"	[illegible]	2"



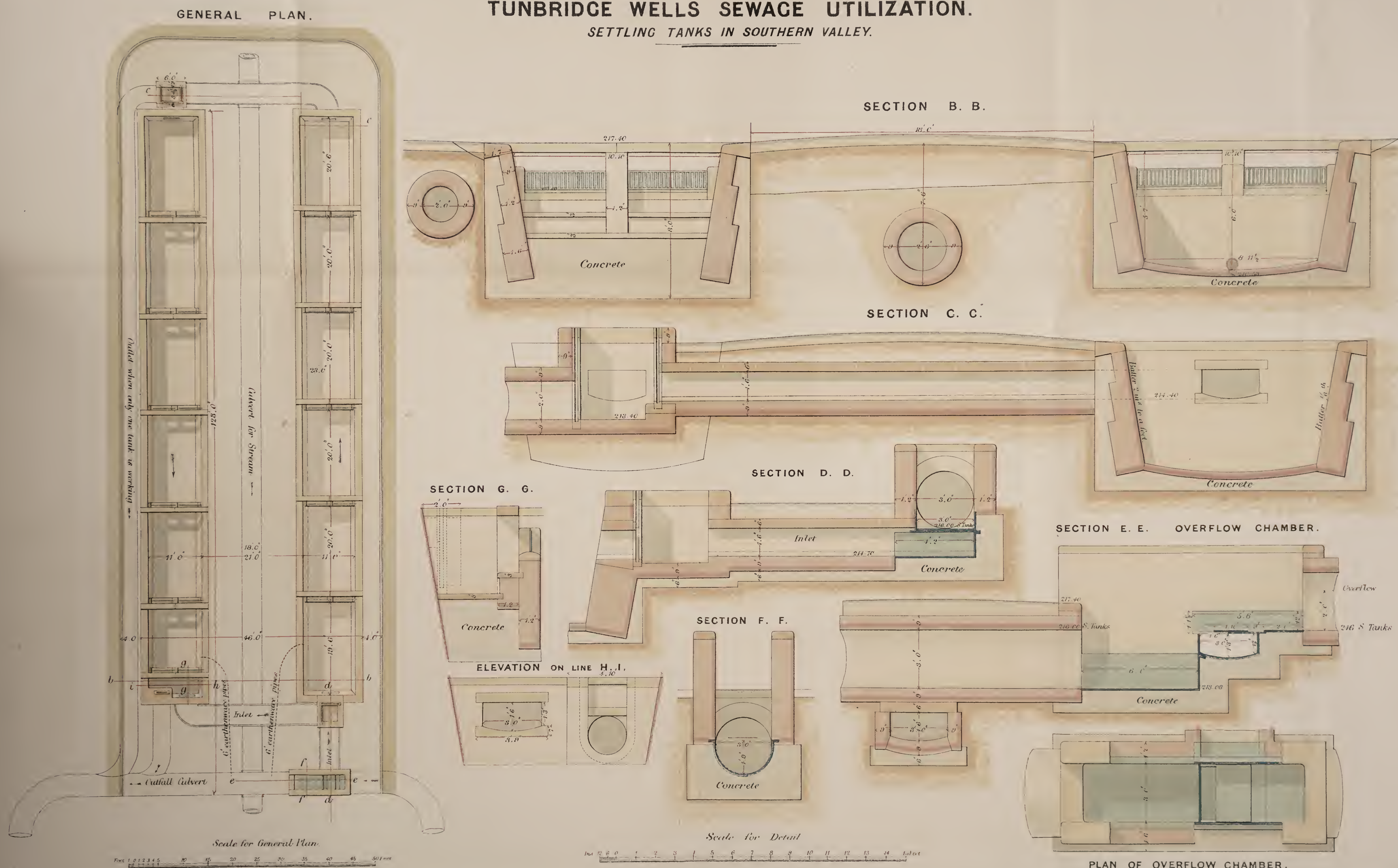

No. 5.
TUNBRIDGE WELLS SEWAGE UTILIZATION.
SETTLING TANKS IN NORTHERN VALLEY.
HALF SECTION OF TANKS A.A.
DETAILS
Present Surface of Ground
Concrete
Concrete
Scale for General Plan
Scale for Section of Tanks, & Cross Wall.
Scale for Sluices
GENERAL PLAN.
CROSS WALL.
Plan showing Screen Grate
Section l l
Section m m
Plan showing flag bridge over tank
3FT SLUICE.
Elevation
Section
2FT SLUICE.
Section
Elevation
Depth of Excavation
at A 8 feet
B 8 1½
C 8 2
D 8 3½
E 8 4
F 8 5½
G 8 6
H 8 4
Inlet
Inlet
Outlet
Outlet
Overflow
Outfall Culvert
2 ft Culvert
Invert 4' 6 below top of bridges
Invert 212. 90, 4' 6" below top of bridges


Nº 6.
TUNBRIDGE WELLS,
PLAN OF SOUTHERN SEWAGE FARM
SHOWING
LINES OF MAIN AND SUBSIDIARY CARRIERS
DRAINS AND OTHER WORKS.
FARM BUILDINGS
FARM BUILDINGS
CATTLE SHED
COTTAGE
REFERENCE.
SCALE.

No. 7.

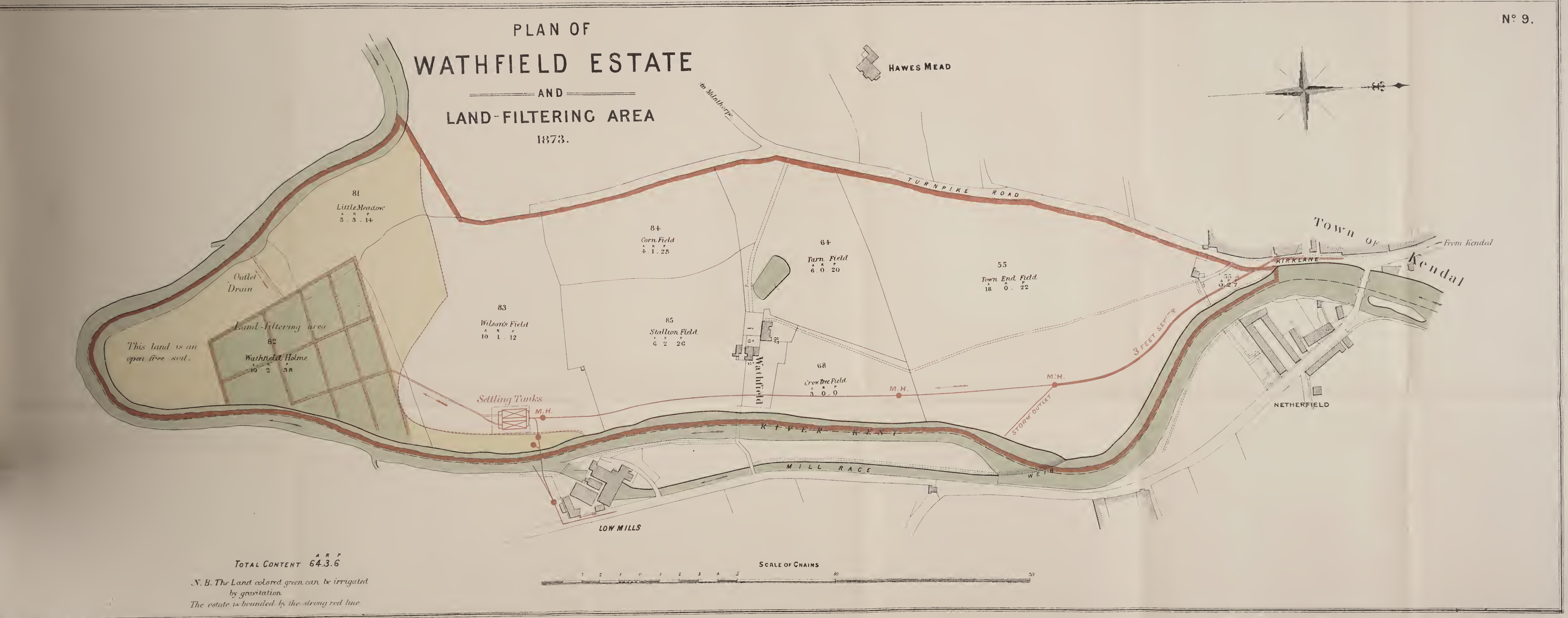
TUNBRIDGE WELLS SEWAGE UTILIZATION.

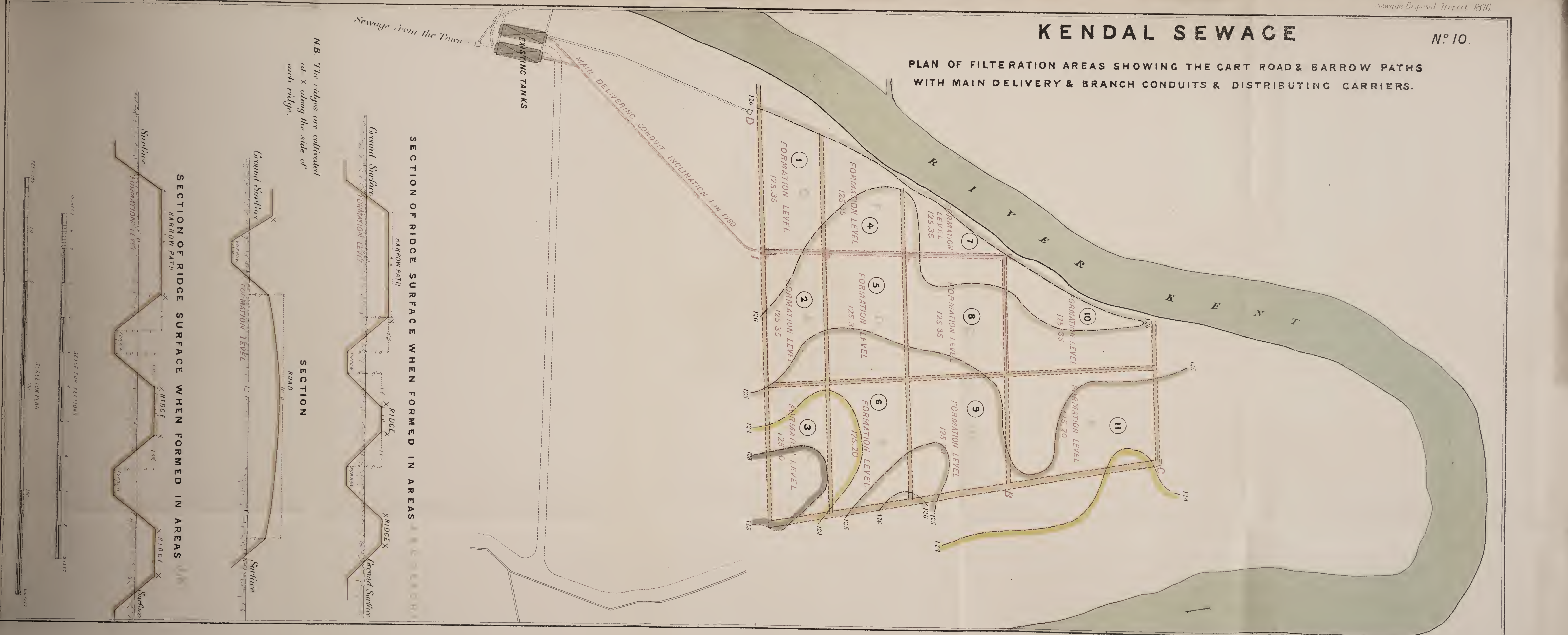
SETTLING TANKS IN SOUTHERN VALLEY.



REFERENCE.

PLOTS.	CONTENTS.	PLOTS.	CONTENTS.
A	9·81 Acres	L	19·37 Acres
B	7 04 ,,	M	4 22 ,,
C	5·95 ,,	N	4·95 ,,
D	16 64 ,,	O	11·57 ,,
E	7 44 ,,	P	9·52 ,,
F	7 67 ,,	Q	10 80 ,,
G	9 90 ,,	R	8 48 ,,
H	9 46 ,,	S	6 46 ,,
J	13 54 ,,	T	5 74 ,,
K	7 02 ,,	V	15 07 ,,
Clock Ho. &c.	3 70 ,,	Cottage &c.	58 in Plot E
Willows ..	2 51 ,,	,,	67 ,, N
Plumb Tree	24 ,,	,,	30 ,, V


No. 9.
PLAN OF
WATHFIELD ESTATE
AND
LAND-FILTERING AREA
1873.
HAWES MEAD
to Milnthorpe
TURNPIKE ROAD
Town of Kendal
From Kendal
KIRKLANE
81
Little Meadow
A R P
3 . 3 . 14
84
Corn Field
A R P
4 1 . 25
64
Tarn Field
A R P
6 0 20
55
Town End Field
A R P
18 0 . 22
Outlet Drain
Land-filtering area
82
Wathfield Holme
A R P
10 2 38
This land is an open free soil.
83
Wilson's Field
A R P
10 1 . 12
85
Stallion Field
A R P
6 2 26
Wathfield
68
Crow Tree Field
A R P
3 0 . 0
3 FEET SEWER
M.H.
M.H.
M.H.
STORM OUTLET
Settling Tanks
RIVER KENT
MILL RACE
WEIR
NETHERFIELD
LOW MILLS
Total Content A R P 64.3.6
N. B. The Land colored green can be irrigated by gravitation
The estate is bounded by the strong red line
Scale of Chains
10
20



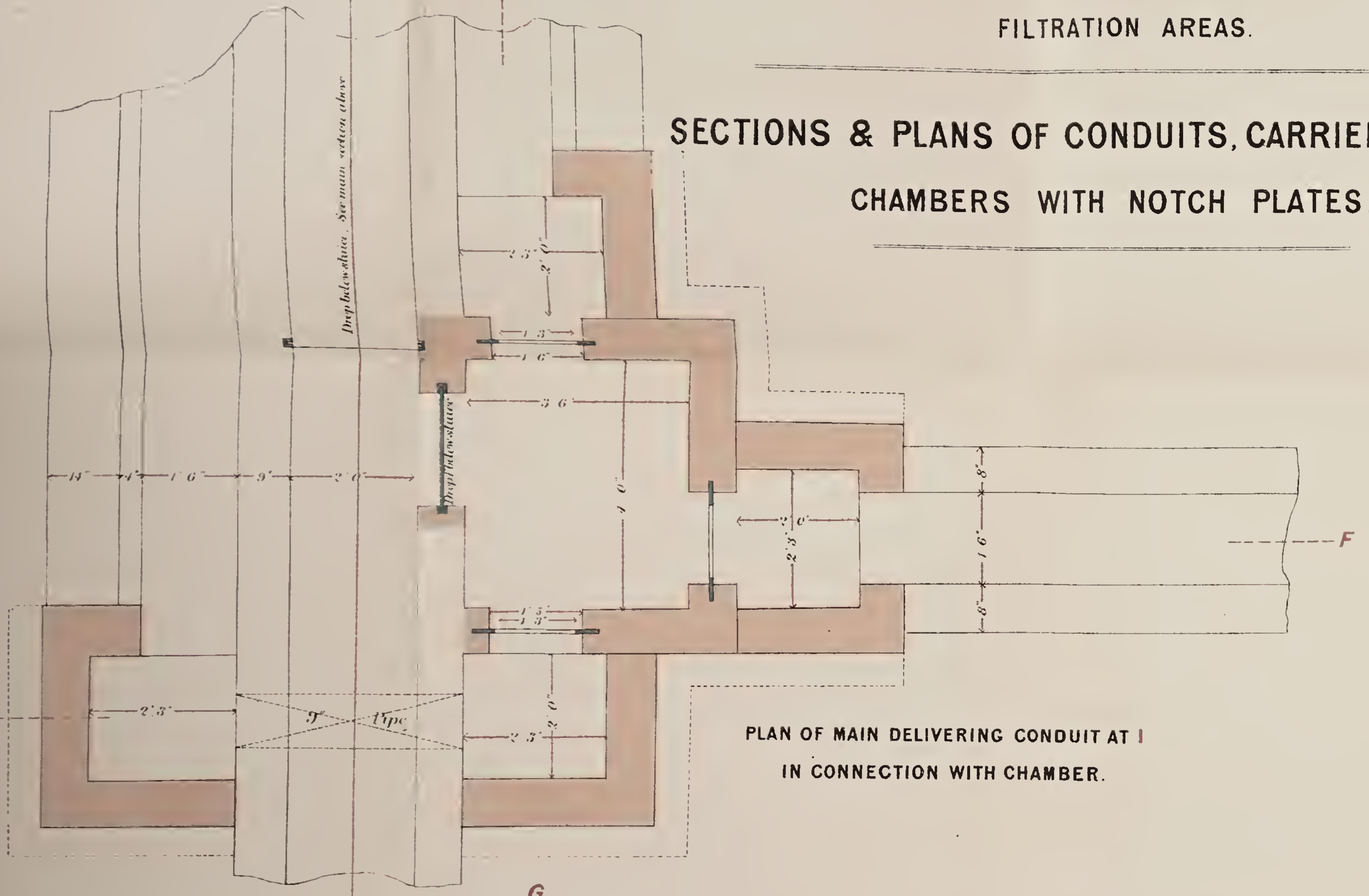
KENDAL SEWAGE
No. 10.
PLAN OF FILTERATION AREAS SHOWING THE CART ROAD & BARROW PATHS WITH MAIN DELIVERY & BRANCH CONDUITS & DISTRIBUTING CARRIERS.
RIVER KENT
Sewage from the Town
EXISTING TANKS
MAIN DELIVERING CONDUIT INCLINATION 1 IN 1760
1 FORMATION LEVEL 125.35
2 FORMATION LEVEL 125.35
3 FORMATION LEVEL
4 FORMATION LEVEL
5 FORMATION LEVEL
6 FORMATION LEVEL 125.20
7 FORMATION LEVEL 125.35
8 FORMATION LEVEL 125.35
9 FORMATION LEVEL
10 FORMATION LEVEL 125.35
11 FORMATION LEVEL 125.20
SECTION OF RIDGE SURFACE WHEN FORMED IN AREAS
BARROW PATH
RIDGE
Ground Surface
FORMATION LEVEL
SECTION
ROAD
Surface
N.B. The ridges are cultivated at X along the side of each ridge.
SECTION OF RIDGE SURFACE WHEN FORMED IN AREAS
SCALE FOR SECTIONS
SCALE FOR PLAN

N°11.

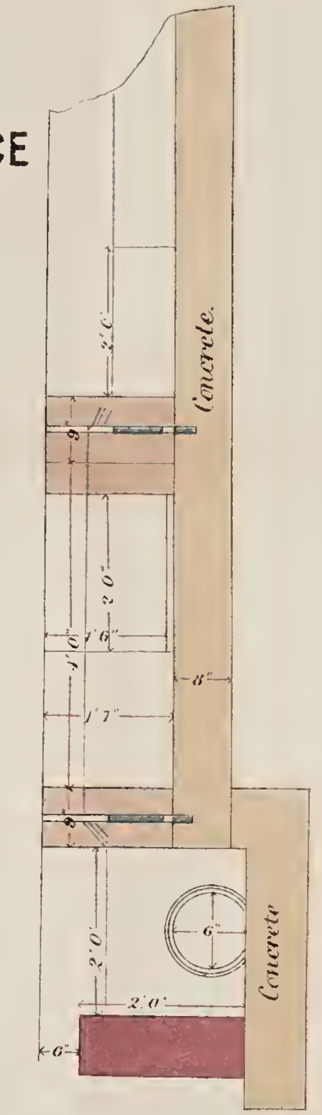
KENDAL SEWAGE,

FILTRATION AREAS.

SECTIONS & PLANS OF CONDUITS, CARRIERS & SLUICE CHAMBERS WITH NOTCH PLATES.



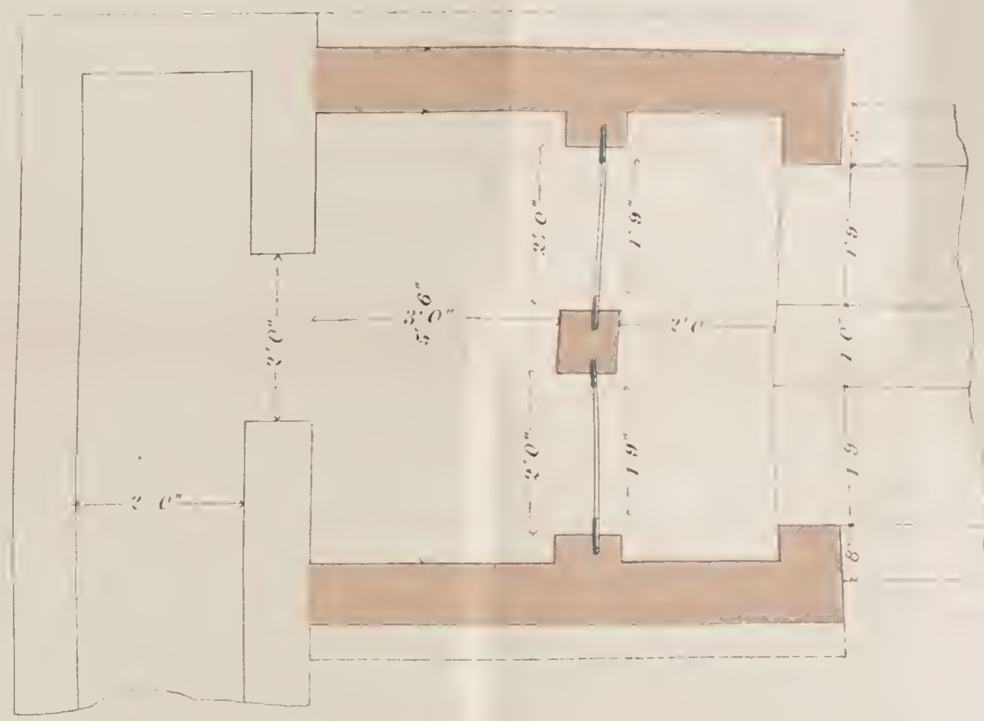
PLAN OF MAIN DELIVERING CONDUIT AT I IN CONNECTION WITH CHAMBER.



SECTION ON G.H.

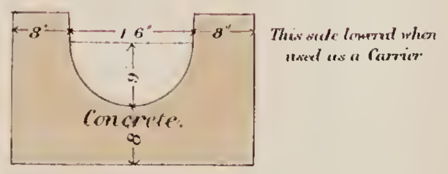
NOTCH PLATES.

		Notch above		Hole below	
		Width	Depth	Width	Depth
for Area	A	14½"	4"	2⅞"	2"
" "	B	14½"	4	2⅞	2"
" "	C	16	4"	3¼	2"
" "	D	16"	4"	3¼"	2"
" "	E	16"	4"	3¼"	2"
" "	F	13"	4"	2⅝	2"
" "	G	18½	4"	3¾	2"
" "	H	18½	4"	3¾	2"
" "	I	8"	4"	1⅝	2"
" "	J	21"	4"	4¼	2"
" "	K	24"	4"	1¾	2"

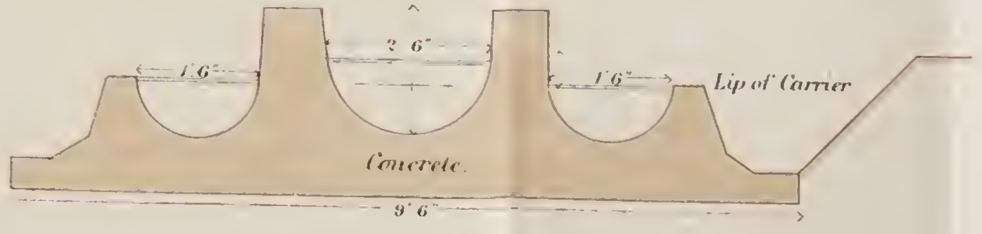


PLAN OF MAIN DELIVERING CONDUIT AT J IN CONNECTION WITH CHAMBER.

SECTION ON E.F.



Scale for Enlargements



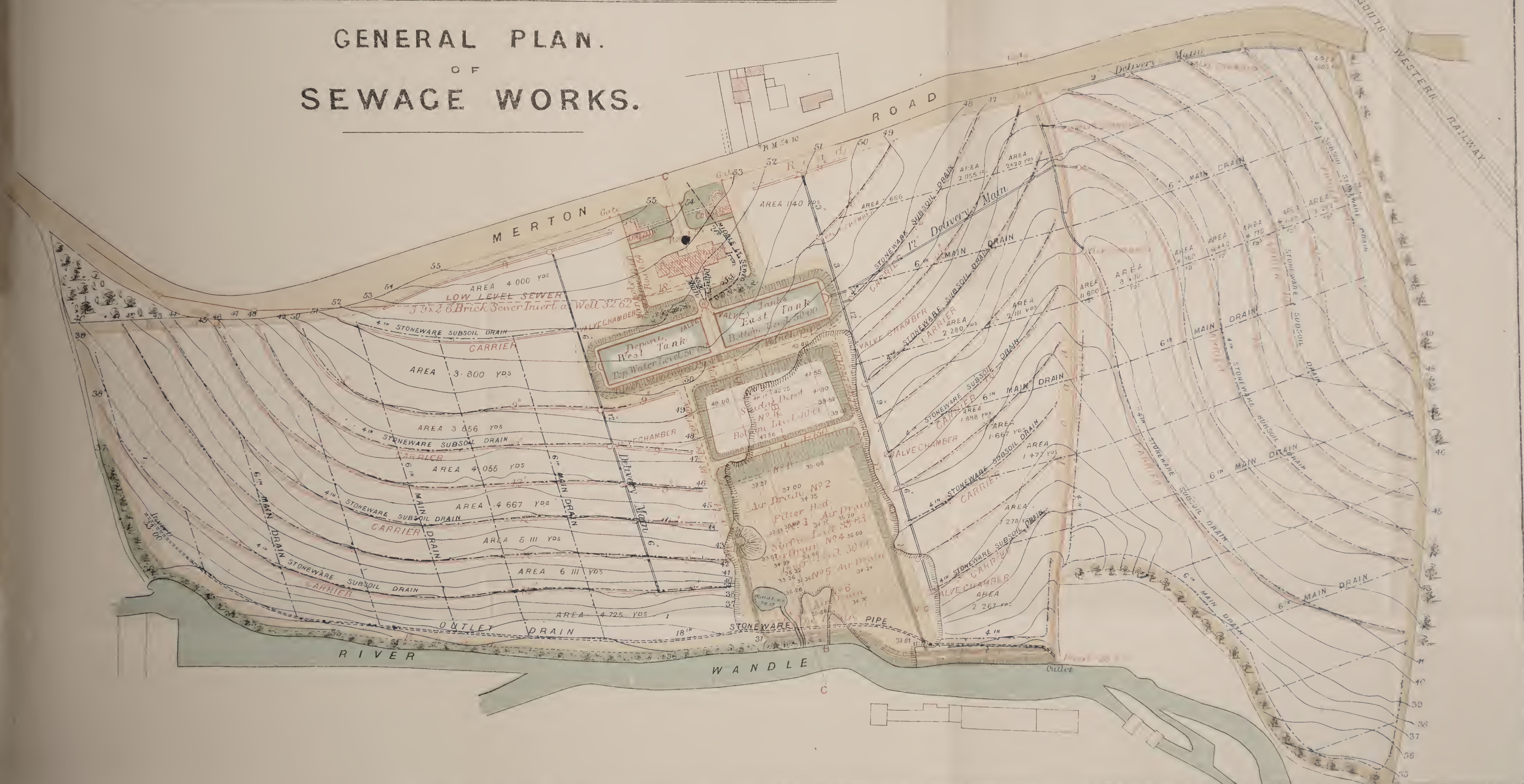
CROSS SECTION OF MAIN DELIVERING CONDUIT & CARRIERS.

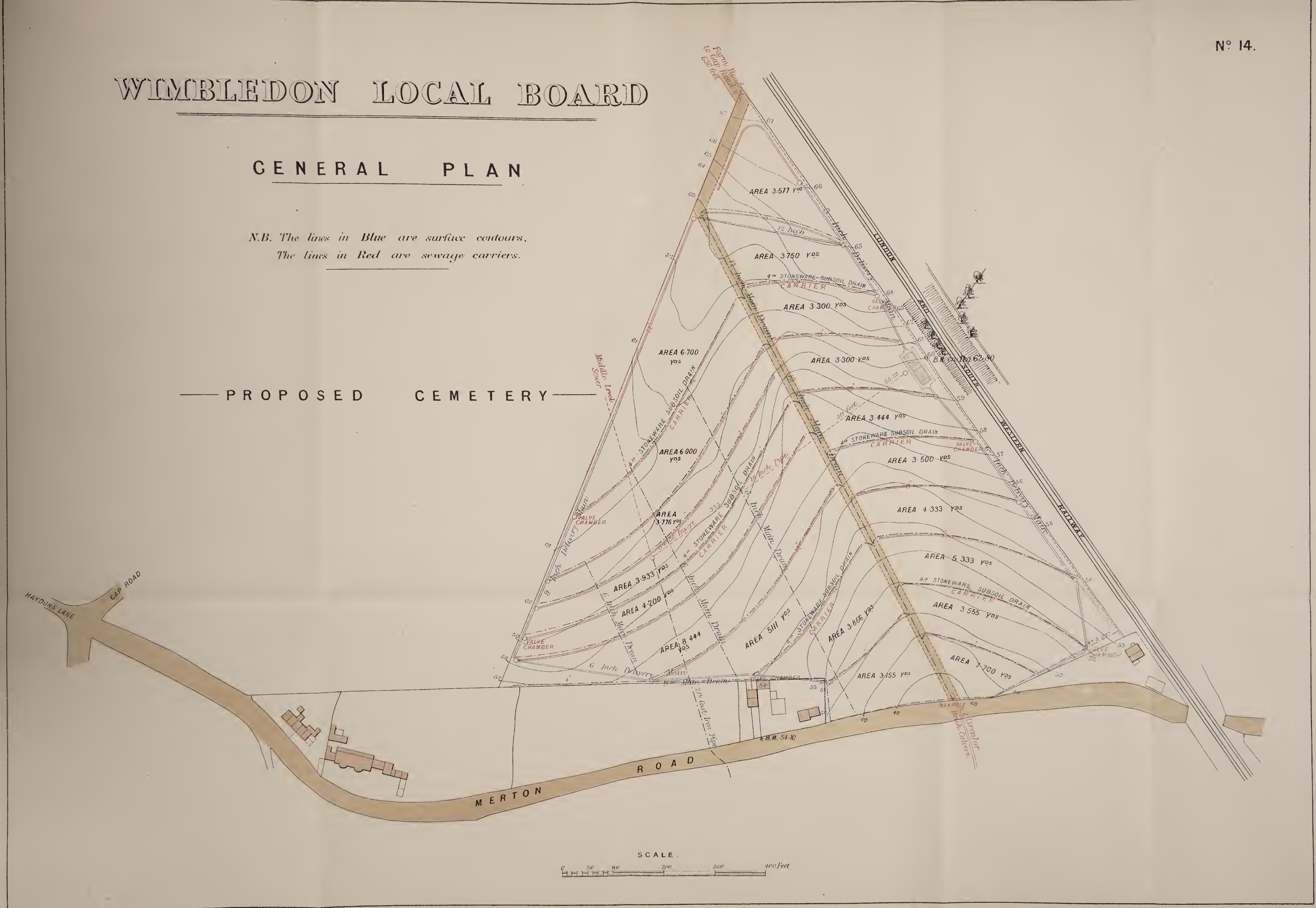
Frederick Langerne, Lith. 22, Bedford Street, Covent Garden, London.

WIMBLEDON LOCAL BOARD

GENERAL PLAN OF SEWAGE WORKS.

Nº 13





Dangerfield Lith. 22 Bedford St. Covent Garden

RIVERS POLLUTION PREVENTION ACT, 1876

REPORT

TO

THE LOCAL GOVERNMENT BOARD

BY

DR. R. ANGUS SMITH, F.R.S.,

ONE OF THE INSPECTORS UNDER THE ACT.

Presented to both Houses of Parliament by Command of Her Majesty.

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PART I.

PART II.

TO THE LOCAL GOVERNMENT BOARD.

My Lords and Gentlemen,

The position which I hold as Inspector under the Rivers Pollution Prevention Act has led me to consider the question of water, pure and impure, from various points of view, and I have brought forward several investigations which I hope will be found of value.

The first part relates to questions which rise to the surface when we study the analysis of water, and mainly to the decompositions which take place in the organic matter often found in water.

The second part relates to the action of air on sewage, and to the mode of treating sewage so as to hasten the aeration. This includes remarks on the relation which the results bear to the latest microscopic inquiries on the germs of disease, and water supply.

The third part relates to the purification of sulphureous liquids draining from alkali works, and to the action of air upon them; with a few experiments on effluents from several other works.

These inquiries are continuations of work done in former years, the earliest going back to 1846, if not prior.

It is really so difficult to come to a conclusion on the many questions that rise before one, that I have not attempted to do much more than to give my results, and leave them to do their work in ripening the mind. Further inquiries may modify all I have to say here, but I think the matter will in any case be of use on the road of progress. I would call attention to the decomposition of organic matter by nitrates, or vice versâ; the use of the oxygen of the nitrates in oxidizing organic matter, and giving out the nitrogen of the nitrates; to the use of aeration in preventing putrefaction, and to its use in throwing down the sulphur from the sulphides under the given conditions; that is, by the constant sulphuration and oxidation of manganese.

If in some cases I may appear to bring forward earlier papers in quotation too often, I may be forgiven, as there is always an inclination to put aside earlier work, and occasionally one feels inclined to show that in former times he has been on the right track, and not in the way of misleaders.

PART I.—WATER AND SEWER WATER.

No. I.

Some Changes effected by Oxygen on Organic Bodies in Water—Formation and destruction of Nitric Acid.

In a magnificent paper by Messrs. Gilbert and Lawes (Phil. Trans., 1861, p. 508), read in 1860, it is said, when speaking of the sources of nitrogen in vegetation,—

" Other investigations to which we have to call attention will throw some light upon the character of the molecular forces by which the decomposition of nitrogenous organic compounds is effected under such circumstances as we have been considering. These forces might be one or both of two kinds :—

" 1. They might be of an oxidising character, analogous to that of the action of chlorine upon ammonia by which free nitrogen is evolved.

" 2. They might be of a reducing character similar to that of a great number of substances upon the oxygen-compounds of nitrogen, by which the oxygen of the latter is appropriated, and free nitrogen given off.

" 3. These two actions may operate in succession the one to the other.

" It is well known that an oxidising action may be so intense as to deprive a nitrogenous organic compound of all its carbon and hydrogen, converting it into oxygen compounds, as is done by permanganic acid. The converse action of the transformation of oxygen-compounds of nitrogen into ammonia is also very well known. An intermediate stage in either of these converse actions may give free nitrogen."

In the account of an investigation " on the amount and " composition of the rain and drainage waters collected at " Rothampstead, 1881," written by Dr. Lawes, Dr. Gilbert, and Mr. Robert Warrington, Part II., page 25, speaking of the loss of nitrates in the soil, it is said,—

" This reduction in question has been effected by the organic matter of the soil, and has resulted in the formation of carbonic acid gas. A part of the nitric acid has probably been reduced to ammonia, while a considerable part of the nitrogen has most likely taken the form of nitrogen gas."

The idea of such a decomposition of nitric acid by organic substances as to give out free nitrogen has been very clearly in the minds of the authors named.

I shall add some of my early work and opinions, as well as a page or two of my latest work, showing that in some conditions free nitrogen is given off by organic substances with great rapidity. It may seem at first that such a point was not of very great importance, but it has such an important bearing on the pollution of rivers question, or, we may say, rather on the purification of water, that it might have been treated even more fully than it

is, and it seems to be a suitable point with which to begin the subject afresh.

In a previous paper read in 1867, and in one in which I spoke of the importance of examining the condition of the organic matter in water, and not merely showing its amount, I divided the organic matter into seven sections:—

1. Organic matter decomposed or putrid.
2. Organic matter readily decomposed and ready to become putrid.
3. Organic matter slow to decompose.
4. Recent organic matter.
5. Old organic matter.
6. Vegetable organic matter.
7. Animal organic matter.

I might express it differently now.

I was interested in showing the development of organisms in the water as a mode of finding the quality of the organic matter. The idea was correct, and the use of the microscope for the purpose correct abstractly; but the subject must pass into the hands of men who have devoted much time to the study of the changes which take place in minute forms. I think I was right in my mode of dividing the organic matter chemically; and, seeing that the study of the germs of disease threatens to be difficult and complicated for a long time to come, it seems to be the duty of chemists to do something towards examining questions relating to organic matter in their own way. I have turned, therefore, more of late to the study of changes which take place in the ammonia, nitric acid, and oxygen, so as to find by chemical methods if the water has active organic matter in it. I do not say that I have made much progress in it, but I have done some work which seems to me interesting.

I may as well here give an extract showing some of my previous views and procedure (Mem. Lit. and Phil. Soc., Manchester, 1867):—

"If the water contains organic matter in solution, or in a condition approaching in all appearance to solution, it may be wholesome or unwholesome. The mere existence of organic matter is no proof of impurity. We must know if it brings animalcules or vegetable life, or products of putrefaction. We must know the quality as well as the quantity. If the matter is peaty, consisting of the ordinary humous class of acids and salts, the colour may be very dark, and the water very unpleasant to look at, without being in any way, so far as I have ever heard, injurious to health, although such water cannot be quite so wholesome as pure water, since the oxygen of solution is diminished. The taste and other sensible qualities will be the chief guides.

"If the matter is wholly or nearly colourless it may still be wholesome or unwholesome. It may, for example, contain the juices of plants of a wholesome character. If these juices are fresh they may do no injury; but they will not remain long fresh; they will putrefy. Water containing organic matter

ready to putrefy ought to be avoided, as we cannot tell when the moment of danger begins, whilst the quality at best is never known to us exactly.

"To ascertain the nature of the organic matter the water is allowed to stand for a day or two, in which case it may be found that *organised bodies* show themselves. Sometimes plants seem completely to fill the vessel, having come out of a moderately clear solution. When standing in this case, the water must be prevented from evaporating, and it must be in glass, so as to be exposed to light; a temperature suiting vegetation is also to be given. Animalcules may appear in great numbers. They are an indication of nitrogenous matter, and one proof of the presence of substances capable of putrefaction. It may be that some form of putrefaction will be the only result; but whether this occurs alone, or along with organised forms, an excess of organic matter is proved. Water that will not bear the test of standing will in most cases be rejected at once. If no other can be obtained, it ought to be used before the putrefactive process has begun; but this is very dangerous. The next best method is to wait till after putrefaction has terminated, and the products are separated as much as possible. This is popularly known to be the case when the water has for some time become clear and colourless and free from smell and taste."

"Water with green organic matter in suspension or semi-solution is generally full of germs of living things and nauseous to the taste."

The oxidation of nitrogen has been a favourite subject of late, but I should not think of attending to it for that reason. However, it may be known to a few chemists that I made nitric acid or nitrates from organic matter in water at a very early stage, as seen in the vol. of the Trans. of the British Association in 1848. I cannot, therefore, be said to be late in the field.

Regarding the deoxidation I may quote from my paper of 1867, speaking of nitrates: "the oxygen seems to be removed as the oxygen of the air is, leaving the nitrogen to pass off as gas." Mem. Lit. and Phil. Soc. of Manchester, vol. 4, ser. 3rd, 1867–8.

When doing the first experiments, spoken of in 1848, I used generally, if not always, yeast for the organic matter, and I did not give to the organised bodies the credit of producing the action. The interesting experiments, however, of M. Schloesing and of Mr. Robert Warington cause every one to reconsider the subject. I suppose M. Pasteur gave the first idea of the action of organisms in nitration, but, so far as I remember, did not prove it. The idea that all nitrates are the products of oxidation of animal matter in contradistinction to vegetable is another point which compels us to think over the subject. I have always objected to the opinion that they were the products special of animal life, knowing that my own experiments were made with vegetable substances. It has, on the other hand, been said (long ago in conversation with me,—I do not remember

if the idea is published,) that probably the vegetable life passed into animalcular life, and thus nitrates were the products only of animals. This is hypothesis, and cannot go far. We must separate the idea of the action of Bacteria, or any vegetable or animal forms of organic matter, from the idea that organic matter must itself be animal before it passes into nitrates, leaving it possible that nitrates may come from decomposing vegetation.

Then, again, the drainage of peat lands frequently contains nitrates, as we know, in great abundance, but the peat itself is not remarkable for much animal life. I find Mr. Warington thinking otherwise as to the amount of nitrates. Our experiences differ on this point, but there is a great variety of peat.

On account of these facts the conditions become complicated, and I am now led to believe the following:—

1. Animal or vegetable matter containing nitrogen produces nitrates by oxidation under certain conditions, with and without organisms.

2. Inorganic matter containing ammonia does the same.

3. Albuminous matter in a putrefactive condition, if exposed to excess of air, produces an oxidation of organic nitrogen.

4. A peculiar putrefactive condition produces a deoxidation of nitrates. In some conditions nitrogen is eliminated as gas, the oxygen going to the carbon in whole or in part. In weak solutions, containing water enough to absorb the carbonic acid, nearly pure nitrogen may be obtained with considerable rapidity.

Two of these propositions may require proof and explanation.

It will be seen in this view of the question that nitrogenous bodies have a peculiar power of taking up oxygen and of giving it out. They seem to be used for the purpose of purifying organic substances as transferrers of oxygen. Although we have not proved, so far as I know, that in cases of great impurity nitrates are formed, and their oxygen given out afterwards, yet we can prove that when the impurity is moderate nitrates are formed, and in any case they give out their oxygen in this way.

The escape of free nitrogen from solutions of organic matter has been noticed, by Reiset, for example, (see Jahresbericht der Chemie fur 1856, p. 806,) and by myself, in the examination of the gases of putrefaction, in 1863 (Mem. of the Lit. and Phil. Soc. of Manchester). I certainly doubted if this was an action of organisms when I found that the nitrogen was evolved at a heat equal to 160° F. or 71·1° C. At the same time there was evolved a great deal of sulphuretted hydrogen. The putrefactive substance then used was blood very much diluted.

I had occasion lately to examine several mixtures. One was formed by the evaporation of urine, and some fæces in the process for drying employed by Mr. Alfred Fryer; and, reverting to my old idea that nitrogen might be given off, I put nitrate of potash in various amounts into solutions of the substance. Bubbles of gas began to escape next day, and in some cases came off with great rapidity and regularity, *i.e.*, about one bubble in three seconds.

Many organic fluids were tried, but the same rapidity was not obtained by any other, although nitrogen was found escaping from blood, egg albumen, and flour paste in the same conditions, that is, the putrefactive state being overpowered by nitre. It did not, however, escape so rapidly as in the liquid mentioned previously.

The nitrate of potash was decomposed and ceased to be found in the liquid. Sulphuretted hydrogen did not exist, or it was found in minute quantities only, and it was clear that the action was entirely different from putrefaction simple. The gas was frequently collected, and it was found to contain very little, sometimes only a trace of, carbonic acid. At the same time the action seemed to be caused by organisms; that is, it took place in liquids which had a great amount of organic matter ready to assert itself. And this I leave for the moment, under a belief that this may be a kind of fermentation; certainly it seems a very new kind. It is like a reversed putrefaction, and must be carefully noted down in considering the action of disinfectants.

This action not being quite the same as that found by Schloesing, where nitrogen was slowly given out, I put down here many of the experiments to illustrate it:—

1. 1100 c. c. of water, containing 10 per cent. of excreta (concentrated by Fryer's apparatus), gave off no gas during $2\frac{1}{2}$ months.

2. 1100 c. c. of water, containing 10 per cent. of excreta and 2 grms. KNO_3 (nitre), commenced to give off gas after 12 hours. The gas collected over water

$$N = 98{\cdot}4 \text{ per cent.} \quad CO_2 = 1{\cdot}6 \text{ per cent.}$$

3. 1100 c. c. of water, containing 10 per cent. of excreta and 2 grms. nitre, gave off 218 c. c. of pure nitrogen when collected over water. (2 grms. nitre contain 220·6 c. c. N.)

4. 340 c. c. of water, containing 10 per cent. excreta and 0·5 grm. nitre per litre, gave off 14·8 c. c. nitrogen collected over water. (The nitre contained 18·7 c. c.)

5. 350 c. c. of water, containing 10 per cent. excreta and 1·0 grm. nitre per litre, gave off 38 c. c. N collected over water. (The nitre contained 37·4 c. c.)

6. 350 c. c. of water, containing 10 per cent. excreta and 0·25 grm. nitre per litre, gave off 7·5 c. c. N collected over water. (The nitre contained 9·6 c. c.)

7. 340 c. c. of water, containing 10 per cent. excreta and 1·0 grm. nitre per litre, gave off 38·0 c. c. N collected over water. (The nitre contained 37·4 c. c.)

8. 320 c. c. of water, containing 10 per cent. excreta (fresh sample) and 0·5 grm. nitre, gave off 53·8 c. c. N collected over water. (The nitre contained 55·1 c. c.)

9. 330 c. c. of water, containing 10 per cent. excreta (as No. 8) and 1·0 grm. nitre. Gas collected over water was nitrogen only.

10. 560 c. c. of water, containing 10 per cent. excreta (as No. 8) and 5·0 grms. nitre. Gas collected over water was nitrogen only.

11. 1100 c. c. of 10 per cent. excreta from a previous experiment, with 2 grms. nitre, were mixed with a second quantity of 2 grms. nitre. Decomposition commenced at once, but continued very slowly. A gas evolution went on for many days. Liquid became strongly alkaline.

12. 1100 c. c. of 10 per cent. excreta from a previous experiment, with 2 grms. nitre, were mixed with 1,980 c. c. of water containing 2 grms. nitre in solution. Decomposition commenced at once; the gas collected over water was pure nitrogen. Liquid became strongly alkaline.

13. 440 c. c. 10 per cent. excreta (as No. 8) and 5 grms. nitre were heated to (120°–125° F.); gave off gas after 30 hours. The speed was much slower than in those experiments at the ordinary temperature.

14. Putrid blood + 3 grms. nitre gave off much gas, which, when collected over water, consisted of pure nitrogen.

15. 1100 c. c. urine + 0·5 grm. nitrate of ammonia + 5 c. c. putrid urine, gave off 70 c. c. of N.

16. Egg and water with nitre gave off gas consisting of 77·8 per cent. N and 22·2 per cent. CO_2, collected over mercury. When collected over water the nitrogen only was obtained.

17. Blood with $(NH_4)_2CO_3$ carbonate of ammonia and KNO_3 gave off gas, which consisted of nitrogen when collected over water.

18. To a quantity of blood which had stood several weeks without apparent change about 2 grms. KNO_3 were added; a brisk evolution set in after 2 days.

Gas collected over mercury = N = 92·6, CO_2 = 7·4.

Gases collected over Mercury.

19. 406 c. c. blood + 1 grm. KNO_3 gave off gas consisting of 96·1 per cent. N and 3·9 per cent. CO_2.

20. Flour paste + 1 grm. KNO_3 gave off gas consisting of N = 97·0, CO_2 = 3·0.

21. Flour paste + 2 grms. KNO_3 gave off gas consisting of N = 6·4, CO_2 = 93·6.

22. Egg diluted with 8 vols. of water KNO_3 gave off gas slowly for some days, N = 85·4, CO_2 = 14·6.

23. 205 c. c. blood + 1 grm. KNO_3 gave off gas consisting of N = 84·5, CO_2 = 15·5.

24. 1150 c. c. blood + 1 grm. KNO_3 gave off gas consisting of N = 48·5, CO_2 d 51·5.

25. 235 c. c. bloo + 2 grms. KNO_3 gave off gas consisting of N = 94·4, CO_2 = 5·6.

In experiments Nos. 8, 9, 10, and 13 the gas evolution did not commence until the third day, the earlier specimen yielding gas much more readily. Urine when fresh did not yield gas at first, unless a small quantity of old urine was mixed with it. The solutions became more alkaline according to the amount of nitre decomposed, forming carbonate of potash.

In 11 and 12 the nitrogen came off slowly at first, but when the first charge was exhausted a second charge of nitre caused the gas to come off instantly.

The gases were exploded with oxygen and hydrogen separately, and also in conjunction with water gases. They were also treated with caustic potash and pyrogallic acid, but only carbonic acid and nitrogen were found.

No. II.

Abstract of Work by Kuhlmann, Boussingault, Schloesing, and Reiset.

In 1848 (Jahresbericht, vol. 1, page 385) Kuhlmann found that nitrates were formed by heating sulphate of ammonia and sulphuric acid with bichromate of potash, peroxide of manganese, brown peroxide of lead, minium, or barium peroxide; also that by heating sulphate of ammonia with nitrate or chlorate of potash, the ammonia is completely converted into nitrous gas.

Kuhlmann (Ann. Chim. Phys., 1847, XX., p. 223 et seq.) produces ammonia from nitrates by—

a. The reducing action of zinc or similar metal and dilute sulphuric acid.

b. The action of sulphuric acid, or, better, hydrochloric acid, upon sulphide of iron in contact with a solution of nitrate.

c. The action of sulphide of arsenic dissolved in solution of caustic potash.

d. Gradually acidulating a solution of sulphide and nitrate of potash. Ammonia is formed after some days.

e. The reducing action of ferrous or stannous oxide. After several days a notable amount of ammonia is formed.

f. Passing a current of sulphuretted hydrogen through a solution containing $SbCl_3$ and KNO_3.

He also obtains nitric acid from ammonia by the following reactions:—

1. By distilling a mixture of bichromate of potash, strong sulphuric acid, and sulphate of ammonia.

Equation:—

$$8\,(2\,CrO_3,\,KO) + 3\,(SO_3\,NH_3\,HO) + 32\,(SO_3\,HO)$$
$$= 8\,(3\,SO_3,\,Cr_2O_3) + 8\,(SO_3\,KO) + 3\,(NO_5\,HO) + 41\,HO.$$

(There seems some error here.)

2. By distilling a mixture of weak sulphuric acid, binoxide of manganese, and sulphate of ammonia.

Equation:—

$$8\,MnO_2 + SO_3\,NH_3\,HO + 7\,SO_3\,HO$$
$$= 8\,SO_3\,MnO + NO_5\,HO + 10\,HO.$$

3. By heating a mixture of nitrate or chlorate of potash with sulphate of ammonia. The whole of the ammonia is converted into nitrous gas.

4. By acting with strong sulphuric acid on a mixture of peroxide of lead and sulphide of ammonium.

5. By acting with strong sulphuric acid on a mixture of peroxide of barium and sulphate of ammonia.

6. As published in 1838, by passing air mixed with ammonia through red-hot tube of porcelain, a small quantity of hyponitric acid and binoxide of nitrogen is formed.

These important facts, which I have confirmed by similar experiments, show at least that nitric acid may be formed by inorganic agents in solution, as well as by explosions in which nitrogen gas itself is oxidized.

In the *Compt. Rendu*, vol. 66, 1868, p. 177, M. Reiset speaks of the production of *nitrous gas* when the liquids become too slightly acid during the fermentation of beetroot solutions.

M. Th. Schloesing, vol. 66, 1868, p. 237, speaking of putrefaction in tobacco juice, says: "Nitrates decompose so rapidly "that the solutions may be found to differ from day to day. "When the nitrates are decomposed, the gases, when carbonic "acid is absorbed, leave a residue containing protoxide of "nitrogen. Urine was found to give out protoxide and binoxide "of nitrogen." The decomposition of nitrates has not been observed when the solutions remained acid. When they became neutral or alkaline the decomposition commenced, and developed with such activity that all the nitrates disappeared in a few days.

In *Compt. Rendu*, vol. 76, p. 22, 1873, M. Boussingault speaks of the disappearance of a small amount of nitrogen in soils, but his chief object is to show that nitrates were not formed from the nitrogen of the air.

Vol. 84, *Compt. Rendu*, p. 301. MM. Th. Schloesing and A. Muntz give experiments to show that the destruction of germs by chloroform prevents the formation of nitrates. This result seems in conformity with other results, but Mr. Otto Hehner thinks a large amount necessary, as I understand him. *Chem. News*, vol. 39, pp. 26 and 53.

A fuller abstract of M. Schloesing's work may be usefully published, as below:—

Study of Nitrification in Soils (*Abstract.*)
(*Compt. Rendu*, vol. 77, pp. 203 and following.)

The necessary conditions for nitrification are known, namely, a nitrogenous substance capable of slow combustion, sufficient aeration, a carbonated base, a certain amount of moisture and heat.

These may be arranged in several categories:—

1. Conditions pertaining to the soil:—Mineral composition and the physical properties resulting therefrom, nature and proportion of the saline constituents soluble and insoluble, nature and quantity of organic matters, amount of cultivation.

2. Conditions resulting from the joint action of the soil and atmosphere:—Humidity proportion of O and CO_2 in the atmosphere contained within the soil, interchange of gas between the soil and atmosphere.

3. Purely physical conditions:—Heat, light, electricity.

Influence of the Proportion of Oxygen in a Confined Atmosphere.

Five quantities of a calcareous earth were placed in long glass vessels, at the ordinary temperature; the only difference being

the composition of the atmosphere in each, which consisted of air and nitrogen as follows :—

No. - - -	1	2	3	4	5
Per cent. by vol. of O	1·5	6·0	11·0	16·0	21·0

Humidity of the earth 15·9 per cent.

Nitrogen in the moist earth = 0·263 per cent. A fertile earth rich in humic matter.

The air was deprived of CO_2 and NH_3 before reaching the earth. The experiments lasted from 5th July till November 7th, 1872.

The following are the mean results for the CO_2 in the atmosphere expelled from the soils during the months of July and August. The temperature varied between 21 and 29°.

No. - - -	1	2	3	4	5
Mean T. - -	24·3	24	23·1	24·2	25·2
Mean CO_2 formed in 24 hours per kilo. of earth -	Mgm. 10·4	Mgm. 16·6	Mgm. 16·1	Mgm. 15·1	Mgm. 19

In the last four cases the combustion of the organic matter appears almost independent of the amount of CO_2; and in the 1st case, where the O = only 1·5 per cent., the amount of CO_2 formed is 60 per cent. of that formed in the others ;—a difference between the slow oxidation in soils and ordinary combustion.

The determinations of CO_2 made in September and October at temperatures between 14° and 18° call for the same remarks. They show, moreover, that temperature has a considerable influence. The production of CO_2 at 16° is only half that at 24°.

The following are the results of HNO_3 determinations calculated in mgms. per kilo. of earth :—

No. - - -	1	2	3	4	5
7th Nov. 1872 -	151·8	201·8	238·6	352·7	268·7
5th July 1872 -	106·1	106·1	106·1	106·1	106·1
HNO_3 formed -	45·7	95·7	132·5	246·6	162·6

The nitric acid present at first = 1528 mgm.

Schloesing fancies Nos. 4 and 5 have been transposed.

The production of HNO_3 depends on the amount of oxygen in the atmosphere.

Second series, differing only in the degrees of humidity which was raised to the maximum, viz., 24 per cent. In No. 1 pure nitrogen alone was used, and Nos. 2, 3, 4, and 5 had atmospheres containing 6, 11, 16, 21 per cent. oxygen.

The experiments lasted from 18th November 1872 till 3rd July 1873.

The CO_2 determinations in November and December gave as means—

No. - - -	1	2	3	4	5
Per cent. oxygen in atmosphere -	0	6	11	16	21
T. - - -	14·3	14·5	15·0	16·1	14·2
CO_2 formed mgm. per kilo. earth -	9·03	15·09	16·0	16·6	16·0

The results are similar to the earlier ones. The excess of moisture favours the oxidation; the temp. being lower.

Estimation of the Nitric Acid.

No.	1	2	3	4	5
3rd July 1873	0·00	263	286	267	289
8th November 1872	64·0	64	64	64	64
Nitric acid lost	64·0.				
Nitric acid formed	-	199	222	203	225

In No. 1 the nitrates have been destroyed, doubtless by the organic matter. In the others the nitrifications have been fairly equal.

The mode of decomposition of nitrates, when the medium is a soil deprived of oxygen, has not been to my knowledge the object of an exact examination. To 12 kilos of earth from Boulogne were added 7·5 grms. KNO_3 in dilute solution, the whole was placed in a 10 litre vessel with a gas evolution tube.

Moisture of the earth	= 17·46 per cent.
Nitric acid originally present	= 0·844
Nitric acid added as KNO_3	= 4·0095
	4·8535

The experiment commenced on the 20th November 1872.

The mercury at first rose in the evolution tube, owing to absorption of oxygen and CO_2. After five days the pressure began to increase again. On the 9th December it was equal to that of the atmosphere. On the 19th a violent evolution of gas commenced. Some gas was lost. At the end of the experiment 4200 c. c. of N and 1300 mgm. CO_2 were collected, other gases were absent.

Analysis of the earth :—

Nitric acid	0·00
NH_3 in 100 grms. before experiment	0·51 mgm.
NH_3 in 100 grms. after "	1·35 "
Gain	0·84 "

2nd experiment, conducted chiefly to measure initial and final volumes of N :—

Weight of earth	11·4 kilos.
Moisture	18·2 per cent.
Temperature (surrounding)	5·5°.
Air introduced	5·0215 litres.
Do. do. (corrected)	4·8904 "
N =	3·8732 "
O =	1·0172 "

Contraction at first as in previous experiment.

Analysis of the earth :—

Nitric acid	- - - -	0·00
NH_3 in 100 grms. earth	before experiment -	1·35
	after ,, -	3·04
Gain	- - -	1·69

Gain of NH_3 for 11·4 kilos earth -	192·7 mgm.
NH_3 equivalent to 7·5 grms. KNO_3 -	126·2 ,,

Analysis of the gas - -	CO_2	N
Vol. at 0° and 760, recovered by the pump - -	3484·2	4088·5
Do., disengaged during experiment - -	89·1	809·4
	3573·3	4897·9

Nitrogen present in air at first - - -	= 3873·2
Nitrogen present in 7·5 grms. KNO_3 - -	= 828·0
	4701·2

There is thus more N given off than is present in the air and KNO_3.

Boussingault has shown that in a confined oxygenated atmosphere the gaseous nitrogen does not go to form nitrates, which indeed lose a small quantity of their combined nitrogen. Schloesing confirms this last result.—Th. Schloesing, *Compt. Rendu*, vol. 77, p. 353.

No. III.

Oxidation of Ammonia.—Experiments made some Years ago, and leading up to the Points explained in No. I.

The peculiar effect of the nitrates has led me into the question of the oxidation of ammonia further than previously because there seemed to be a question as to the action of organisms. I am desirous of saying that I have no desire to give my experiments in opposition to Mr. Warrington. The only experiments that were caused by reading Mr. Warrington's were those relating to the action of light and those where heat was used. I so far corroborate Mr. Warrington that light does retard the action in organic solutions. The action of organic matter is further shown by the fact that where there is most organic matter in a state readily decomposed by caustic potash that is in so-called albuminoid matter, the action of decomposing nitrates is strongest.

Pure water containing 0·1 per cent. milk, filtered through sand free from nitrites and nitrates.

The sand was about 8 inches deep and 1 inch broad.

1st. 100 c. c. filtered from December 2nd to December 20th, 1874, contained 0·185 mgm. HNO_3.

2nd. 100 c. c. filtered from December 2nd to December 20th, 1874, contained 0·170 mgm. HNO_3.

100 c. c. not filtered, kept in a bottle half a day, 0·148 mgm. HNO_3.

100 c. c. of the water used, filtered through sand from December 2nd to December 20th, 1874, 0·00.

The remaining portions were again filtered till 28th January 1875, making altogether 46 days, when—

1st gave - - -	0·163 mgm. HNO_3.
2nd „ - - -	0·148 „ „
Pure water - - -	0·00.

There is a slight increase in the amount of HNO_3 by filtration from the 2nd to 20th December, 18 days; and afterwards to January 28th, the 46th day, there is a decrease, but not so small as in the unfiltered portion. Pure water filtered through the sand for 46 days remained free from HNO_3.

Ozonized air with phosphorus vapour aspirated through water containing milk, and water made alkaline containing yeast. January 1875.

Through 50 c. c. water containing 0·01 per cent. yeast for 85 hours, extending over 5 days, strong reaction to ozone paper - - - -	No HNO_3 formed.
Through 50 c. c. water containing 0·01 per cent. milk for 69 hours; 50 c. c. of caustic soda pure were then added, and the ozonized air again aspirated for 95 hours, altogether 164 hours -	No HNO_3 formed.
After passing the 0·01 per cent. milk solution, the ozonized air was aspirated through water containing 0·01 per cent. yeast for 164 hours - - -	No HNO_3 formed.
And finally through another 50 c. c. water containing 0·01 per cent. yeast for 164 hours - - - -	No HNO_3 formed.

When the aspiration was stopped all the liquids were alkaline, and gave a reaction with ozone paper. Each portion smelled of phosphorus.

Permanganate and yeast:—

0·3 grm. yeast mixed with water and permanganate of potassium, stood 20 days - - - -	No HNO_3 formed.

Hydrogen peroxide and yeast:—

0·3 grm. yeast mixed with water and 25 c. c. H_2O_2 solution, stood 20 days.

The 0·3 grm. yeast contained before mixture - - - -	0·444 mgm. HNO_3.
After mixture with H_2O_2 solution, and standing 20 days - -	0·193 mgm. HNO_3.

There has been a decrease in the amount of HNO_3.

Reduction of Nitrate by H_2S in slightly Acid and in slightly Alkaline Solutions.

Both columns were determined in the same way by reduction with aluminium.

——	Milligrammes HNO_3.	
Bottle, loosely closed with paper, December 5th, 1875. 200 c. c. KNO_3 solution + 1 c. c. NaHS solution + 0·5 c. c. Acetic Acid. Acid - - - - -	1st day. 8·750	39th day. 8·214
Bottle stoppered do. do. do. -	8·750	8·214
Open, December 5th, 1875, 200 c. c. KNO_3 sol. + 0·5 c. c. NaHS sol. + 0·1 c. c. $\bar{A}$ - - - -	8·750	41st day. 8·177
Stoppered do. do. do. -	8·750	8·326
Open, December 5th, 1875, 100 c. c. KNO_3 sol. + NaHS sol. 0·25 c. c. Alk. - - - - -	4·375	42nd day. 4·012
Closed do. do. do. -	4·375	4·012
		38th day.
Open, 200 c. c. KNO_3 sol. + 1 c. c. NaHS sol. Alk. - -	8·750	8·194
Closed do. do. - -	8·750	8·342
Open, 200 c. c. KNO_3 sol. + 2·5 c. c. NaHS sol. Alk. -	8·750	8·405
Closed do. do. -	8·750	8·105
Open, 200 c. c. KNO_3 sol. + 5 c. c. NaHS sol. Alk. - -	8·750	8·356
Closed do. do. -	8·750	8·504
Open, 200 c. c. KNO_3 sol. + 5 c. c. NaHS sol. + 0·5 c. c. $\bar{A}$ Alk.	8·750	8·357
Closed do. do. do. -	8·750	8·504
Open, 200 c. c. KNO_3 sol. + 10 c. c. NaHS sol. Alk. - -	8·750	8·561
Closed do. do. - -	8·750	8·483
Open, 200 c. c. KNO_3 + 0·25 c. c. NaHS + 0·1 c. c. $\bar{A}$ Alk. -	8·750	8·153
Closed do. do. do. -	8·750	8·301
Closed, 200 c. c. KNO_3 + 10 c. c. NaHS sol. + 0·7 c. c. $\bar{A}$ Alk.	8·750	8·561
H_2S was found in two bottles only. After 39 days these were alkaline.		

I have spoken of the oxidation of organic nitrogen, and we must now consider the oxidation of inorganic nitrogen or ammonia.

Oxidation of Free and Acid Solutions of Ammonia by Hydrogen Peroxide.

——	Milligrammes HNO_3 in the Total Liquid.	Milligrammes HNO_3 in the Re-agents before mixing.
10 c. c. NH_3 solution + 50 c. c. H_2O_2 solution. Tested after eight months - - -	14·45	0·77
10 c. c. NH_3 solution, acidified with 20 c. c. dilute H_2SO_4 + 50 c. c. H_2O_2 solution. Tested after eight months - - - - -	3·56	1·29
10 c. c. NH_3 solution, acidified with 10 c. c. dilute H_2SO_4 + 20 c. c. H_2O_2 solution. Stood exposed to light from February 20th, 1874, to March 24th, 1874 - - - -	1·48	0·89
30 c. c. NH_3 solution + 55 c. c. H_2O_2 solution -	12·28	0·81

LATER EXPERIMENTS.

OXIDATION OF AMMONIA.

Permanganate of Potash, 5 p. c. sol., Ammonia, 5 p. c. sol., and Sulphate of Ammonia, 2 p. c. sol. Oxygen and Nitric Acid in Parts per Million.

—	20 c.c. $KMnO_4$ sol. 3 c.c. $(NH_4)_2SO_4$ sol. 1 c.c. NH_4OH sol. Water to 1 litre.			20 c.c. $KMnO_4$ sol. 1 c.c. NH_4OH sol. Water to 1 litre.			20 c.c. $KMnO_4$ sol. 3 c.c. $(NH_4)_2SO_4$ sol. Water to 1 litre.			40 c.c. $KMnO_4$ sol. 6 c.c. $(NH_4)_2SO_4$ sol. 2 c.c. NH_4OH sol. Water to 1 litre.			60 c.c. $KMnO_4$ sol. 9 c.c. $(NH_4)_2SO_4$ sol. 3 c.c. NH_4OH sol. Water to 1 litre.		
	HNO_3 formed.	Available O lost.	Days in Contact.	HNO_3 formed.	Available O lost.	Days in Contact.	HNO_3 formed.	Available O lost.	Days in Contact.	HNO_3 formed.	Available O lost.	Days in Contact.	HNO_3 formed.	Available O lost.	Days in Contact.
1880.															
1st Oct.	9·34	16	1	11·12	8	1	—	0	1	16·3	32	1	21·49	79	1
29th ,, -	20·00	—	29	—	—	—	—	—	—	—	—	—	59·3	—	29
1st Nov.	—	—	32	—	—	—	—	—	—	—	—	—	—	—	—
4th ,, -	23·2	47	35	15·2	63	35	2·67	0	35	23·8	126	35	104·5	379	35
12th ,, -	17·0	47	43	14·1	63	3	6·67	16	43	23·0	632	43	206	491	43
1881.															
19th Jan.	81·5	95	111	55·6	103	111	4·45	32	111	97·8	660	111	267	679	111
29th Mar.	52·6	289	180	34·7	281	180	7·71	211	180	77·8	680	180	278	1,158	180

OXIDATION OF AMMONIA.

PERMANGANATE of POTASH, AMMONIA, and SULPHATE OF AMMONIA. Oxygen and Nitric Acid in Parts per Million.
5 p. c. sol. 5 p. c. sol. 2 p. c. sol.

—	80 c. c. $KMnO_4$ sol., 12 c. c. $(NH_4)_2SO_4$ sol., 4 c. c. NH_4OH sol. } Water to 1 Litre.			160 c. c. $KMnO_4$ sol., 24 c. c. $(NH_4)_2SO_4$ sol., 8 c. c. NH_4OH sol. } Water to 1 Litre.			160 c. c. $KMnO_4$ sol., 24 c. c. $(NH_4)_2SO_4$ sol. } Water to $\frac{1}{2}$ Litre.			160 c. c. $KMnO_4$ sol., 8 c. c. NH_4OH sol. } Water to $\frac{1}{2}$ Litre.			160 c. c. $KMnO_4$ sol., 24 c. c. $(NH_4)_2SO_4$ sol., 8 c. c. NH_4OH sol. } Water to $\frac{1}{2}$ Litre.		
	HNO_3 formed.	Available O lost.	Days in Contact.	HNO_3 formed.	Available O lost.	Days in Contact.	HNO_3 formed.	Available O lost.	Days in Contact.	HNO_3 formed.	Available O lost.	Days in Contact.	HNO_3 formed.	Available O lost.	Days in Contact.
1880.															
1st Oct.	22·24	32	1	28·16	759	1	7·41	—	1	17·8	751	1	21·5	711	1
1st Nov.	63·0	—	32	68·2	—	32	8·52	—	32	72·6	—	32	75·6	—	32
4th „ -	203·1	601	35	308	1,959	35	11·12	—	35	661	3,397	35	1,127	4,898	35
12th „ -	241	664	43	—	2,214	43	20·7	632	43	667	3,607	43	1,082	4,962	43
1881.															
19th Jan.	427	980	111	623	2,708	111	35·6	948	111	1,112	4,424	111	889	5,530	111
29th Mar.	454	1,092	180	845	3,438	180	32	3,016	180	949	5,601	180	1,601	6,808	180

OXIDATION OF AMMONIA.

SPECIMENS HEATED PREVIOUSLY. Solutions as before.

1·606 grm. $KMnO_4$, 50 c. c. $(NH_4)_2SO_4$ sol., 50 c. c. water. After heating to 100° C. for 2 hours— $HNO_3=390$, Permanganate still present.	2·339 grm. $KMnO_4$, 50 c. c. NH_4OH sol., 50 c. c. water. After heating to 100° C. for ½ hour— $HNO_3=830$, Permanganate still present.	Between 1 and 2 grm. $KMnO_4$ (about 1 grm.), 100 c. c. NH_4OH sol. After heating to 100° C. for 1 hour— $HNO_3=734$, Permanganate all reduced. Considerable evolution of gaseous nitrogen.	50 c. c. NH_4OH, 50 c. c. $(NH_4)_2SO_4$, 1·5 grm. $KMnO_4$, 100 c. c. water. After heating to 100° C. for 2 hours— $HNO_3=216$, Permanganate all reduced.	5 c. c. NH_4OH, 5 c. c. $(NH_4)_2SO_4$, 5 c. c. $KMnO_4$. The permanganate was in one limb of a bent tube and the ammonias in the other; after being heated to 100° C. for 2 hours the solutions were mixed— $HNO_3=38·91$ mgm. NH_3 present=333·65 mgm. 5 c. c. NH_4OH, 5 c. c. $KMnO_4$, Treated as above— $HNO_3=26·7$ mgm. NH_3 present = 297·5 mgm.

OXIDATION OF AMMONIA.

Results given as Nitric Acid in Parts per Million.

—	Mixed 31st May.	Mixed 31st May.	Mixed 11th June.	Mixed 27th August.	Mixed 27th August.	Mixed 30th August.	Mixed 30th August.	Mixed 1st Sept.	Mixed 1st Sept.
	10c.c.1%$KMnO_4$sol., 5 c.c.$(NH_4)_2SO_4$ sol. 100 c.c. Pure Water.	5c.c.1%$KMnO_4$sol., 5c.c.$(NH_4)_2SO_4$ sol. 100 c.c. Pure Water.	200 c.c. $KMnO_4$ sol., 25c.c.$(NH_4)_2SO_4$sol., 50 c.c. NH_4OH sol. Water to 1 Litre. $KMnO_4$ all reduced to MnO_2 in 1 Day.	200 c.c. $KMnO_4$ sol., 25c.c.$(NH_4)_2SO_4$sol., 10 c.c. NH_4OH sol. Water to 400 c.c. Alkaline. Exposed to Daylight.	200 c.c. $KMnO_4$ sol., 25c.c.$(NH_4)_2SO_4$ sol. Water to 400 c.c. Neutral. Exposed to Daylight.	200 c.c. $KMnO_4$ sol., 25c.c.$(NH_4)_2SO_4$sol., 10 c.c. NH_4OH sol. Water to 400 c.c. Alkaline. Kept in Darkness.	200 c.c. $KMnO_4$ sol., 25c.c.$(NH_4)_2SO_4$ sol. Water to 400 c.c. Neutral. Kept in Darkness.	25 c.c. H_2O_2 sol., 25c.c.$(NH_4)_2SO_4$ sol. Water to 400 c.c.	25 c.c. H_2O_2 sol., 25c.c.$(NH_4)_2SO_4$sol., 10 c.c. NH_4OH. Water to 400 c.c.
1880. May 31	0·62	0·16							
June 11	..	..	2·43						
„ 15	..	..	446·0						
(about) Aug. 27	..	..	..	6·0	6·0				
„ 30	..	..	667	1057	..	6·0	6·0		
Sept. 1	..	..	..	..	..	..	..	0·8	0·8
„ 2	5·41	4·45	630	1123	6·0	806	..		
„ 17	5·58	4·84	756	1297	7·4	..	88·9		
Oct. 1	..	..	741	1601	10·6	889	96·4	8·3	80·0
Nov. 4	..	..	783	..	..	..	..	8·21	88·9
1881. Jan. 19	..	..	623	1660	48·9	1037	..	16·7	21·3
Mar. 29	..	..	..	2490	68·9	2501	..	7·26	9·04

OXIDATION OF AMMONIA.

Blood Solutions.—Heated.

0·969 grm. $KMnO_4$ and 100 c. c. 1°/o blood solution were heated separately to 100° C. for 2 hours and then mixed, 23/9/80. After 4 days' contact—

$$HNO_3 = 37 \cdot 36 \text{ parts per million.}$$

0·819 grm. $KMnO_4$ and 100 c. c. 1°/o blood solution with 1 c. c. pure NaOH solution were heated separately, as above, 23/9/80. After 4 days' contact—

$$HNO_3 = 29 \cdot 65 \text{ parts per million.}$$

0·480 grm. $KMnO_4$ and 100 c. c. 1°/o blood solution treated as above. After 4 days' contact—

$$HNO_3 = 28 \cdot 91 \text{ parts per million.}$$

There is here mentioned a series of trials made some years ago by passing air drawn over phosphorus, first through pure water, to find if the reagents were pure. After 60 hours the water was found to contain in 10 c. c. 0·01 mgm. of ammonia, and that in contact with phosphorus contained no nitric acid.

This phosphorised or ozonized air drawn through water for a week produced no nitric acid in it.

Then through dilute ammonia for three days no nitric acid.

Another (time not recorded) gave 0·22 mgm. HNO_3.

It will be seen from the tables that an ammoniacal condition greatly increases the nitric acid. This action of the alkaline state is probably an explanation of the effect produced in the presence of chalk, and may explain the amount of nitrates in at least some chalk waters. The water having organic matter in it and percolating through the chalk has this matter more readily oxidized.

It is clear then that oxidation is continually ready to take place when organic substances are in water, and oxygen is presented to them. This takes place rapidly if air is abundant, but it takes place much more rapidly when oxygen is presented in a concentrated form, as in nitrates, &c.

It may be asked how far this may affect the estimation of albuminoid ammonia when heat is used with permanganates.

The consequence also is that waters with little oxygen in solution are under suspicion, or rather they have or have recently had substances in solution taking up oxygen. I brought this subject forward many years ago, but it is not sufficiently attended to by chemists. Dalton saw the importance of this examination long before our time. It is a merit, which only the best water has, to have the oxygen and nitrogen in the relation of not less than 33 per cent. of the first. Sometimes I have found as much as 35. I do not know if this is an error of experiment; I think not.

We learn that by a natural process all traces of organic impurity may be removed from water, and that part of this may be done more rapidly by the assistance of organisms probably, but that it may be concluded without organisms. The only usual bodies that cannot be removed are the alkalies and their salts, of which chloride of sodium is the most striking. The attention paid to this salt has been too small. I brought this forward also in 1867, but that also was attended to before me by Dalton, and forgotten. I hope it will not again be left out. It is remarkable with what complacency many chemists look on an amount of chlorine in water far above that of the natural drainage of the district.

No. IV.

Further on the Action of the Air on Combined Nitrogen.

The air oxidizes the nitrogen which is found in nitrogen compounds. That this is done when organic substances are absent,

is not proved, so far as I know. The oxidation of inorganic nitrogen seems to require higher oxides than the air. But we may ask, will not the ozone of the air prove to be one of these higher oxides? It is probable, and we may expect it to show its power in some cases, but it cannot be expected to reach far into sewers or heaps of refuse. We may, however, be certain that it acts as a purifying agent on substances which it meets in the atmosphere.

On the table of changes in the condition of nitrogen in water containing organic matter (p. 26) it will be observed that the nitric acid column shows a general increase in every case. There is, however, a curious observation to be made; at a certain time there is a slight diminution, and this has taken place in every instance. It cannot be supposed that amongst so many analyses no error should have occurred, but such a consistent error is not probable. Besides, a similar backward movement occurred on the occasion of a previous inquiry; and, indeed, it agrees with my early observations of the destruction of nitrates, and the later ones on the elimination of nitrogen. Those in the table given all occurred from the end of June to the beginning of August, as if the heat had been an agent, the peculiar putrefaction spoken of having occurred, I suppose.

The nitrogen of the three kinds increases (*i.e.*, of free ammonia, albuminoid ammonia, and nitric acid), being supplied by the residual albumen, which is supposed to be continually decomposing.

The effect of darkness has been to increase the growth of nitrates in the Manchester water, and the stronger blood solution. This is not apparent in the weaker.

It seems correct, from the results already given, to believe that nitric acid has a mode of growth in nature quite independent of organic matter, as well as one which is intimately associated with organic matter. We have arrived at a very firm stage, but we require to learn more. The inorganic matter from which nitric acid is made contains ammonia, and we require now to learn in what conditions nitrogen is used for forming ammonia if there be any methods of doing so.

Schönbein showed long ago that ozone caused the formation of nitric acid; and Luca (Jahresbericht, 1855, p. 318) said that, after passing air ozonized by contact with moist phosphorus for three months over potassium and potash, there was formed nitrate of potash in quantities enough to crystallize; from 7,000 to 8,000 litres of air being used. With these views before us we may look to the formation of nitrates from inorganic nitrogenous compounds in cases where ozone exists, and that may possibly be found in very pure water, where the oxygen exists to the nitrogen in a proportion above 33 per cent. Alkalinity seems an essential condition in many of the mixtures, but I have found nitrates in wells very acid. This was remarkable in the case of a polluted well, the use of which had probably caused

death to more than one of a family in Manchester before the present water supply was universal in the city.

Inferences.

We may then come to the following conclusions :—Bodies containing protein compounds, when in abundance of water and in common air, may oxidise and form nitric acid.

The same organic bodies in a state of decomposition and in water may oxidise at the expense of nitrates, and give out nitrogen.

The first condition is that in which a certain amount of sewage is in the water, but is overpowered by the amount of air.

The second is when the sewage is in excess, and overpowers the nitrates.

Nitrates may be formed by the oxidation of inorganic nitrogen, but not so far as we know by contact with common air under ordinary conditions. The oxygen must be presented in a more concentrated or more active condition.

Putrefaction destroys organic matter without the influence of oxygen ; it breaks up organic compounds, and destroys organisms. The evidence seems to indicate that it destroys even those bodies that produce disease, but that in certain conditions it produces others. This is a point not to be enlarged upon without more knowledge, but it is evident that by putrefaction we get rid of an enormous amount of offensive matter. Oxygen cannot enter under the surfaces of actively putrefying bodies; but whenever it is allowed to enter by the putrefaction being less active, an action begins which in time completes the destruction of the body. We are not, therefore, to suppose that the germs of disease can resist all these efforts of nature to destroy noxious things, nor are we to suppose that an invisible germ of disease can pass on from stage to stage unaffected by the putrefaction of sewage and the action of air. We must believe, for the present, that it is not so. In water we see perfect purification, nitrogen itself being lost.

In ordinary putrefaction sulphuretted hydrogen comes off in abundance, with much carbonic acid and some nitrogen. Oxygen resists this action, and if the oxygen is supplied in a concentrated condition a change takes place, nitrogen is evolved as the principal gas, and a decomposition of nitrogen compounds takes place. Nitrogenous bodies are thus destroyed, in one manner by their voluntary putrefaction, in another by oxidation. Up to a certain point not determined the greater the amount of nitrogenous bodies the more rapid is their decomposition.

The oxygen of the nitrate passes in part to the carbon; some will be retained, forming a carbonate. I have not estimated how much, or if all, is taken by the carbon.

If the solution is weak the nitrogen takes up the oxygen, and does not allow it to pass away, thus forming nitrates.

Putrefaction and oxidation are two well-known modes of destroying organic bodies at ordinary temperatures. The second is not proved to be connected with organisms.

How far then can oxidation or a great supply of air be employed to destroy putrefaction or to purify.

The bearing it has on the analysis of water will be clearly seen by chemists. The bearing on the sewage question is also interesting. Substances and living things may be carried by the rapid sewage system into the range of a new activity before undergoing that putrefaction which breaks them up in proximity to us or in the sewers themselves. It seems to point to a plan of causing the destruction of organisms by putrefaction and subsequent oxidation or by chemical action. At least it seems to me that we require to learn if it be true that any of the germs of disease, or which germs of disease, will live in an abundance of good air. We know that abundant dilution will render them all ineffective. It is probable that there will be a difference amongst them in this respect, whilst all will yield to the double action of first putrefaction and then oxidation.

On oxidation, more will follow, when speaking of its application to sewage, &c.

Changes in the condition of NITROGEN in WATER containing ORGANIC MATTER.

The figures indicate parts per million.

Date.		Days Standing.	Manchester Water in Light.				Manchester Water in Darkness.				0·25 c. c. Blood per 10 ltrs. H_2O Light.				0·25 c. c. Blood per 10 ltrs. H_2O Dark.				2·5 c. c. Blood per 10 ltrs. H_2O Light.				2·5 c. c. Blood per 10 ltrs. Water Dark.			
			N as Free NH_3.	N as Alb. NH_3.	N as HNO_3.	The 3 N's.	N as Free NH_3.	N as Alb. NH_3.	N as HNO_3.	The 3 N's.	N as Free NH_3.	N as Alb. NH_3.	N as HNO_3.	The 3 N's.	N as Free NH_3.	N as Alb. NH_3.	N as HNO_3.	The 3 N's.	N as Free NH_3.	N as Alb. NH_3.	N as HNO_3.	The 3 N's.	N as Free NH_3.	N as Alb. NH_3.	N as HNO_3.	The 3 N's.
May	13	Fresh	0·033	0·074	—	—	0·041	0·079	—	—	0·099	0·326	—	—	0·0988	0·212	—	—	0·659	3·33	—	—	0·79	3·66	—	—
	17	4	0·039	0·069	—	—	0·041	0·079	—	—	0·086	0·219	—	—	—	—	—	—	0·728	3·50	—	—	0·833	3·05	—	—
	21	8	0·026	0·072	—	—	0·026	0·074	—	—	0·206	0·454	—	—	0·201	0·461	—	—	1·186	3·97	—	—	1·25	4·20	—	—
	26	13	0·062	0·079	—	—	0·039	0·076	—	—	0·382	0·420	—	—	0·425	0·413	—	—	3·26	3·46	—	—	5·80	2·27	—	—
	31	Fresh	—	—	0·069	—	—	—	0·069	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	31	18	—	—	0·566	—	—	—	0·526	—	—	—	0·666	—	—	—	1·11	—	—	—	2·30	—	—	—	2·46	—
June	7	25	0·036	0·072	0·564	0·672	0·059	0·056	0·577	0·692	0·652	0·298	0·664	1·614	0·665	0·283	0·617	1·565	5·106	1·853	1·33	8·289	7·11	1·78	1·18	10·07
	23	41	0·044	0·066	0·535	0·645	0·106	0·058	0·555	0·719	0·848	0·160	0·544	1·452	0·889	0·173	0·295	1·357	7·11	1·845	1·23	10·185	8·56	1·15	1·03	10·74
July	1	49	0·036	0·079	0·535	0·650	0·119	0·072	0·544	0·735	0·889	0·168	0·513	1·570	0·889	0·168	0·371	1·428	7·71	1·37	1·01	10·09	8·89	0·79	0·624	10·304
August	10	89	0·015	0·058	0·608	0·681	0·021	0·051	0·699	0·771	0·058	0·182	1·540	1·780	0·029	0·015	1·70	1·744	4·61	0·972	4·81	10·392	4·87	0·74	5·06	10·67
	20	99	0·016	0·041	0·657	0·714	0·013	0·044	0·739	0·796	0·130	0·130	1·69	1·950	0·030	0·10	1·73	1·860	3·56	0·91	4·94	9·41	5·45	0·76	5·43	11·64
September	2	112	0·018	0·057	0·666	0·741	0·016	0·064	0·764	0·844	0·099	0·017	1·72	1·836	0·180	0·16	1·74	2·080	4·48	0·89	5·13	10·50	6·26	0·77	5·34	12·37
	17	127	0·020	0·053	0·699	0·772	0·016	0·059	0·732	0·807	0·118	0·132	1·89	2·140	0·036	0·087	2·01	2·133	4·28	0·74	5·51	10·53	5·60	0·59	5·93	12·12
October	1	141	0·021	0·053	0·695	0·769	0·018	0·062	0·967	1·047	0·140	0·112	1·85	2·102	0·036	0·092	1·87	1·998	4·28	0·64	5·50	10·42	6·09	0·54	5·76	12·39
	26	166	0·023	0·054	—	—	0·025	0·059	—	—	0·145	0·109	—	—	0·043	0·100	—	—	4·45	0·724	—	—	6·69	0·591	—	—

No. V.

Oxidation and Decomposition in Sewage.

I feel almost ashamed to bring so many figures to prove so little, but we know that wisdom grows slowly; and the enormous amount of labour spent on sewage within 40 years shows that it has happened also to all my contemporaries as well as predecessors to give their labour to an extent which seems too great for the result. Still, I by no means think that my time is lost if I prove no more than this,—that by agitation with air sewage is kept without smell for two or more weeks in ordinary weather, and even in warm weather. This is probably the most practical portion of this part of the inquiry. The numerous analyses are not at all so telling as I expected them to be, but they do tell something of the chemistry of the sewage in relation to its loss of organic matter, and the change to inorganic. This inquiry, like all inquiries on the subject hitherto, has a preliminary character; but it is a progress in my opinion, and I am desirous of publishing it, whether found at present practicable or not, because I think that in time the practical may be forwarded by it.

The gases from putrefaction I examined some years ago, as elsewhere quoted. In 1877 I made some experiments simply to find if abundance of water increased or diminished the offensive emanations, and these I supposed to be measured by the ammonia. It is shown that the air is much more tainted with ammonia when water is not present: see "Gases from Sewage, &c.," p. 29. Another inquiry going further may follow this, but I look to the microscopist rather than the chemist to complete it.

Gases from Sewage.

The gases from sewage are continually receiving attention, but they are not frequently examined in a quantitative manner. It is very difficult to obtain them in the condition and state of dilution in which they cause illness. It has been observed that these gases produce more cases of illness than gases from excreta not producing sewage, and it seemed of some importance to know what was the proportionate amount of decomposition. The result is insufficiently shown in the table to follow. The atmosphere over the dry matter contains much more ammonia than over the wet. This may not mean that more organic matter is decomposed; it may mean only that the water keeps the ammonia in solution. Still, bubbles of gas rise rapidly from sewage in water; no such rapid evolution takes place with the dry matter. The quality of the decomposition is different. Water assists greatly the growth as well as decay of most organisms, and to these we must attribute the more rapid escape of gas. Still, the experiments point only in one direction, and we have to learn much regarding the quality of the air which comes out so rich in ammonia. This much we learn: that

water assisting the conditions of putrefaction causes a much greater destruction of organic matter, and the emanations are offensive, but we do not hear much of decided injury when they are mixed with a great profusion of air. Perhaps the paper by Dr. Henderson of Helensburgh has touched this point more directly than anything that has been done.—*See* "The Sewage Question in its relation to the Gareloch and neighbourhood."—Helensburgh.

It was natural, however, to inquire what advantage could be got out of this knowledge; and at a later period, after obtaining Dr. Storer's apparatus, a fresh stimulus was given to the inquiry in a new direction.

It will be observed that in the "dry" column the ammonia rises much higher than in the "wet." This would show that, however much gas may escape from sewage, it is never very full of the products of decomposition of animal matter. The result of breathing sewage gases, if more hurtful, must be attributed either to the supply being more abundant, although more dilute, or of a more offensive kind. This latter explanation seems the more probable one, but requires examination. This is quite in agreement with the statement elsewhere made as to the rapid destruction of organic matter in water. We know that there is a stage of great danger, and, when the sewage is diluted and exposed to the atmosphere, a rapid and remarkable stage of diminished, if not disappearing, injuriousness. The materials were kept in carboys holding about eight gallons (36·5 litres); the carboys were kept closed, a certain measure of air drawn out and washed, and an equal amount of fresh air allowed to enter.

Gases from Sewage and Sewage Materials.

Date.	T°C.	NH₃ from the Solid. Free.	NH₃ from the Solid. Saline.	NH₃ from the Solid. Albmd.	NH₃ from the same in Water. Free.	NH₃ from the same in Water. Saline.	NH₃ from the same in Water. Albmd.	——
1877.		Mgm. per cubic metre of air.						
October 17th - -	—	* 8·5			* 7·0			Nesslerised direct without distillation.
„ 18th, 10 a.m. -	—	*10·0			* 7·5			
„ „ 1 p.m. -	—	*10·5			* 7·5			
„ „ 5 p.m. -	—	*10·0			* 5·0			
„ 19th, 10 a.m. -	16°	* 8·0			* 3·5			
„ „ 2 p.m. -	—	* 6·5			* 5·0			
„ „ 5 p.m. -	—	*10·5			* 5·0			
„ 20th - -	16°	* 8·0			* 7·5			
„ 22nd, 10 a.m. -	18°	*20·75			*17·5			Wet, smells strong and repulsive. Dry, more intense than at first.
„ „ noon -	—	*20·0			*19·5			
„ „ 3 p.m. -	18°	*22·5			*25·0			
„ 23rd, 10.30 a.m.	15°	*22·5			*17·5			Corks on carboys removed, and caoutchouc caps substituted.
„ „ 3 p.m. -	17°	*23·5			—			
„ 24th, 10 a.m. -	17°	*31·0			*17·5			Smell from the wet becoming less intense. (The wet had another 50,000 grns. water added.)
„ „ 3.30 p.m.	15°·5	*33·0			*12·5			
„ 25th, 10 a.m. -	16°	*37·5			*22·5			Distilled from alkaline permanganate.
„ 26th, noon -	15°	*52·6			*15·5			
„ 27th, 10 a.m. -	16°	*80·0			*10·0			
		_67·5_			_6_		--	Free. Till 24th no distillations.
„ 29th, 10.30 a.m.	17°	_140_		4·0	_15_		3·5	
„ 30th, 10.30 a.m.	17°·5	_105_		24·0?	_12·5_		2·5	
					0	15·0	1·5	(Acidulated water used to collect the ammonia.)
„ „ 3 p.m. -	18°	_100_		1·6	—	—	—	
„ „ 3.30 p.m.	—	_110_		2·0	8	0	0·8	
„ 31st, 10.30 a.m.	—	0	180	2·0	4·8	0	2·0	
November 1st, 10 a.m. -	16°	170	0	2·5	4·0	0	1·0	
„ „ noon .	17°	140	0	?	—	—	—	
„ 2nd - -	16°5	160	1·5	3·0	4·6	0·2	1·0	
„ 3rd, 10 a.m. -	16°	160	1·0	7·5	2·6	0	1·0	
„ 5th, 9.30 a.m.	16°·5	160	0	2·5	4·4	—	?	
„ 6th, 9.30 a.m.	16°·5	_162·5_		2·0	5·0	—	1·4	
„ 7th, 9.30 a.m.	19°	_225_		—	—	_16_		Soda lime.
„ „ 12.30 p.m.	—	_250_		—	—	_6_		Not distilled.
„ 8th - -	17°	_200_		—	—	_6_		
„ 9th, 10 a.m.	--	_195_		—	—	_5·6_		Do.
					—	_8·2_		Soda lime.

* Asterisks show the three ammonias given ; italics the first two.

Date.	T.	Ammonia from the Solid. Free.	Saline.	Albmd.	Ammonia from the same in Water. Free.	Saline.	Albmd.	—
1877.								
November 10th, 9.30 a.m.	17°	-	200	—		4·4	—	Not distilled before Nesslerising.
						8·6	—	Soda lime.
„ 12th, 9 a.m.	16°	*230*		27·5	*12·0*		3·0	Acidulated water used to obtain the ammonia.
„ 13th - -	15°·5	*150*		7·5	*8*		2·0	
„ 14th, 9.30 a.m.	14°·5	*170*		—	*8·0*		2·6	
„ 15th - -	16°	*215*		4·5	—	8·4	—	
„ 16th - -	16°	*275*		3·0	*7·0*		0·6	Surface.
		290		2·0	—		—	1 ft. from surface.
„ 17th -	—	*230*		5·5	*5·2*		1·2	
„ 19th - -	15°	*200*		6·0	*5·0*		1·0	
„ 20th - -	12°·5	*155*		2·5	*4·8*		1·0	
„ 21st - -	12°	*162·5*		6·0	*4·2*		0·8	
	12°	*149*		—	—		—	By Frankland's method.
„ 22nd -	12°	*250*		6·0	*5·2*		1·6	
		200		—	—		—	Soda lime.
„ 23rd - -	12°	*212·5*		7·0	4·0		1·0	
		200·0		—	—		—	Soda lime.
„ 24th - -	12°	*225·0*		6·0	*7·0*		0·0	
„ 26th - -	10°	*187·5*		2·5	*2·2*		0·4	
		175·0		—	—	2·4	—	Dry by soda lime.
December 1st - -	12°	—		—	—	—	—	
„ 3rd - -	—	*252·0*		2·5	3·0		1·0	
„ 4th - -	13°	—		—	5·0		trace	
„ 5th - -	12°·5	*250·0*		0·5	—		—	
„ 10th - -	—	—		—	*2·2*		1·0	
„ 11th - -	14°	—		—	*1·6*		0·8	
„ 14th - -	12°	*175·0*		—	*0·0*		*4·0	*Albuminoid and saline? Wet carboy well agitated.
„ 17th - -	12°	*250·0*		—	—	—	—	
„ 19th - -	12°	*275·0*		—	0·0	3·6	0·0	
„ 29th - -	11°	—		—	0·6		—	
„ 31st - -	10°	*300·0*		2·5	1·0		0·0	
1878.								
January 2nd - -	10°	*300·0*		—	—	—	—	
„ 21st - -	15°·5	700	10·0	9·0	10·1	1·2	5·4	
„ 25th - -	10°	*600*		7·5	8·0	2·4	1·0	
February 1st - -	14°·5	700	8·0	7·5	11·2	0·0	1·6	
„ 2nd - -	1°	190	4·5	10·5	8·8	4·2	2·6	
„ 4th - -	1°·5	200	8·0	5·5	3·8	0·2	lost	
„ 12th - -	Freezg.	0·00	124·0	4·5	3·6	0·2	1·2	

Flesh, Decomposition of.

Date.	T.	Ammonia. Free.	Ammonia. Saline.	Ammonia. Albmd.	—
1877.					
November 22nd -	—	2·4		0·4	Flesh newly bought, when washed with water, showed ammonia by Nessler's test.
„ 24th -	12°	0·8		0·2	
„ 26th -	10°	6·6		?	Flesh tainted.
„ 28th -	—	2·2		—	
„ 29th -	—	2·0		—	
December 1st -	12°	3·0		—	
„ 3rd -	—	4·4		0·2	Flesh smell putrid.
„ 4th -	13°	5·6		Trace	
„ 5th -	12°·5	11·0		1·0	
„ 7th -	—	13·0		1·4	
„ 8th -	12°	11·8		2·0	
„ 10th -	—	12·8		Trace	
„ 11th -	14°	13·0		Trace	
„ 12th -	—	19·0		Trace	
„ 13th -	11°	14·2		—	
„ 14th -	12°	18·0		—	
„ 15th -	11°	13·0		—	
„ 17th -	12°	22·0		—	
„ 19th -	12°	22·0		—	
„ 20th -	5°	21·0		0·8	
„ 29th -	11°	16·0		Trace	
„ 31st -	10°	16·0		Trace	
1878.					
January 2nd -	10°	22·0		—	
„ 21st -	15°·5	54·0	12·4	3·0	
„ 25th -	10°	70·0	2·4	2·0	
February 1st -	14°·5	70·0	1·6	3·0	
„ 2nd -	1°·0	34·4	0·2	4·4	
„ 4th -	1°·5	34·0	1·0	2·6	
„ 12th -	Freezing	15·2	0·4	0·2	

No. VI.

Earlier Results—Aeration in Water.

This subject has long interested chemists, and aeration has formed one of the plans of engineers from a long date back. The mode of bringing down the water from the hills to Manchester has been founded on the idea that aeration is of value, the artificial falls being constructed with that view. It has also been a common saying that water is best when aerated, and mineral waters aerated to an excessive extent have been in use since first invented by Thomas Henry, F.R.S., of Manchester, last century; although it must be remembered that "aeration" by carbonic acid, as is the case in prepared waters, does not carry out the true idea of aeration which is by the oxygen of the air. "Aeration" by carbonic acid gives a secondary meaning. In order to test the purity of water to be used in distilleries, it was said jocularly in a publication, some 20 years ago, in Scotland, that one asked, "How many falls does the water fall? Talisker water comes down 80 falls." (*See* Highland Drovers, Douglas, Edinburgh.) The idea of purification by air must be considered then as a general one.

Of course water, as such alone, is not oxidized by the air, although a certain amount is held in solution; but water does not exist quite pure or unmixed in nature, and we really mean the destruction of organic matter in it when we speak of purifying water. I am obliged to approach this matter very cautiously because there are already men (one or more) who claim the aeration of water under certain conditions of impurity, such as sewage, as their invention; and it is not for me to state what is their legal position; but it is a long time since I began to study air and water, as well as sewage, as my published papers show, and I may be allowed to save myself trouble by making a few more quotations, instead of writing the old facts in new words, from a paper on "The Mud of the Clyde," Glasgow Philos. Soc. 1880, by R. Angus Smith.

P. 17.—"This raises a question to be solved, but the fact is certain that fevers have not been traced to the escape of gases of putrefaction when there has been a large amount of water and exposure to the air. But they have been found when the water is not very great in amount and the decomposition is made under cover, as in sewers. The question arises, is this owing to the concentration or to the difference of decomposition in darkness, or to the better supply of oxygen? The effect of sunlight in warm countries does not allow us to suppose that the daylight always produces in vapours an innocent state, although it has a great effect in that direction when there is little water . . . . With us, at least, innocence in the atmosphere seems to be rather something connected with the abundance of air in proportion to the impurity. This air may act in two ways. It may act by rapid oxidation of the sub-

stances in water, or by dilution of the gases when formed; and the destruction of putrid matter in water is really very rapid when plenty of air is allowed. This air is brought to the Clyde by the water, and also by the waves, both artificial and natural, exposing a great deal of surface. The air may act also merely by rapid dispersion of the gases. Still we must not forget that these gases or vapours are not reported to us to produce any marked type of disease over the Clyde, even when they come in a state so concentrated as to produce sickness; whereas gases from sewers, in a condition which may not produce immediate illness, may produce in time typhoid fever, as we are credibly informed.

"We must conclude then that it is not mere dispersion, but that it is a more thorough putrefaction and oxidation, which takes place in the Clyde, and a more complete destruction of the organic substance by the abundance of air, than can take place in sewer water, whatever the senses may indicate to us. Of course we must ever give some credit to the flow of air up the river and the ever fresh breezes that come from the Atlantic as well as the mixture of air with water caused by steamers.

"Whilst then there is oxygen enough at present to prevent disease, there is not enough to prevent smells which disgust and cause sickness for the time."

In connection with the purification of streams the following quotation may be added, although written previously:—

"When azotized compounds decompose and form ammonia, how long is this ammonia retained in the water? On examining a very putrid stream, I estimated the amount of ammonia at the most putrid portion, where carburetted hydrogen was passing off in great volumes, and where a cubic foot could be obtained in a very few minutes by stirring.

"In the sewage stream of which I have spoken the amount of ammonia was from 0·5 to 0·7 grain per gallon. After going 14 miles the amount was only 0·07, and after 20 miles none at all was found.

"The mud of the same stream was in a state of putrefaction, and contained per cent.:—

"Ammonia	- - -	0·797
„	a mile lower - -	0·420
„	at second mile -	0·171

"The ammonia rapidly disappeared, and the mud itself diminished very greatly in amount.

"I estimated that one grain of ammonia evaporated in some seasons from every square foot per hour.

"In taking sewage water to the land, I think it very important that the movement should be as rapid as possible.

"The water in its passage of 20 miles has lost its valuable ammonia, and that within two or three days. This is a sufficient proof that we must not trust to the ammonia as an indication of the amount of the organic matter which has been, as it is as rapidly removed as the organic matter is decomposed;

that is to say, the length of time necessary for complete putrefaction is, under favourable circumstances, no greater than the time afterwards required for the removal of its products. In this water there was no life to be observed; but the estimation of the organic matter would have shown no difference, whether vitality had been present, and the substance had been capable of entering into active and unwholesome forms, or had been ready to break up into instantaneous putrefaction, or had been preserved, like a mummy, in carbolic acid for a thousand years.

"From this observation regarding the ammonia we are clearly led to beware, in our schemes of irrigation by sewage water, that the land shall be overflowed before the ammonia is thoroughly formed, or else, if the ammonia is formed, that it shall not be subjected to loss by long exposure to evaporation.

"We see also that nature provides here for the complete obliteration of organic matter. It ceases altogether to be found in the water. It may be traced, either as such, or as ammonia and carbonic acid, long after the bubbles of carburetted hydrogen have ceased to appear, until at last it dwindles down to an amount which is rather difficult to remove from water, and which, so far as we know, may be utterly disregarded.

"In the passage of organic matter we may observe, from figures soon to be quoted, that the volatile and organic matter diminished from 9·33 grains per gallon down to 5·04, even when there was an increase of fixed matter, and that the decomposing matter in solution diminished still more rapidly, in the ratio of 283 to 17.

"The organic matter having left the water, we may next inquire whether any trace of its existence remains behind. That trace we do find in the increased amount of alkalies, sulphates, and chlorides."—Memo. Lit. and Phil. Soc., Manchester, 1867–8; also "Chemical News."

I had also, even so early as 1848, shown the oxidizing action of filtering (report to the British Association already quoted), and in a paper to the Glasgow Philosophical Society, "On the Mud of the Clyde," the following words were used:—

Page 8.—"The long stretch of water lying between Ardmore and Dumbarton is not all an accumulation of mud, which is an indication that the mud falls down,* and is carried off mainly by the deep channels. The channel is inclined to act as a depositing reservoir, and the northern side receives the overflow water. The mud remaining in the channel is carried partly by nature, and as the water leaves the channel it becomes less disturbed and clearer. This water has, of course, some of the lighter and the soluble parts which the putrefying river brings down, but it really seems as if a very large portion of this were rapidly oxidized; and, whilst the neighbourhood is freed from the mud which might continue sending out more gases, the water is rapidly undergoing purification, and it flows then down as the tide goes out, bringing unexpectedly good water below, although, of course, not perfect. We see a rapid change of water about this district.

* *i.e.* before spreading.

"I feel inclined, therefore, to repeat that this space is of great value to all the watering-places of the Clyde, and if it is ever made into arable land they will suffer severely. I only wish it were still larger."

This led to an examination of the effects on the atmosphere of the putrefaction in sewage and sewage materials. The examination, as usual, is not complete, except in one direction; and although the work was done four years ago, I have brought it forward in this Report: see p. 29. It may convey some idea of the work going on when putrefying substances in water are exposed to air in the conditions mentioned. The amount of organic matter becoming decomposed is great, and ammonia is continually given off. The experiments might be continued with advantage by finding the total amount of nitrogen and carbon from a given quantity of material in various conditions, but it is not easy to do this in conditions purely natural.

Report to the Local Government Board by Dr. Angus Smith, F.R.S., as to Treatment of Sewage.

Sir,

As requested (by Mr. Sclater Booth, M.P., late President of the Board) I have the honour to submit a careful examination of five effluents, the results of processes for the purification of sewage water by different methods.

1st. From Aldershot, where irrigation alone is used.
2nd. From Coventry, where precipitation by alum and iron is used first and irrigation afterwards.
3rd. From Birmingham, where precipitation by lime is employed.
4th. From Burnley, where also lime is employed.
5th. From Aylesbury, where the A B C process is used, a precipitant of alum being employed, also of clay.

I shall extract from the larger tables some of the more important points; but I wish it to be observed that in this report I refer to quality of effluents only, and not at all to the ultimate value of processes.

Free Ammonia A.

——	Ammonia abstracted.		Ammonia remaining.	
	Parts per 100,000.	Per Cent. of Total.	Parts per 100,000.	Per Cent. of Total.
Aldershot *b*.	11·755	97·96	0·245	2·04
Coventry	2·06	79·8	0·520	20·2
Aldershot *a*.	2·913	80·10	0·747	19·9
Aylesbury	2·980	74·5	1·020	25·5
Birmingham *a*.	1·425	52·9	1·275	47·1
Burnley	0·120	8·3	1·330	91·7
	added	added		
Birmingham *b*.	0·520	18·8	3·220	118·8

Note.—Aldershot (*a*) specimen collected in wet weather; (*b*) in dry weather Birmingham (*a*) after lime precipitation and irrigation; (*b*) after lime alone.

Free includes saline ammonia. Its existence is of no disadvantage so far as the effect on the atmosphere is concerned, but its absorption by the soil is important as manure. Its amount indicates decomposition. So far as free ammonia is concerned, the first on the list is Aldershot during dry weather, specimen *b*; Coventry stands second. There two processes are used, both precipitation (with alum, iron, and lime) and irrigation. The next is Aylesbury. The lime processes are certainly behind.

ALBUMENOID AMMONIA B.

—	Ammonia abstracted.		Ammonia remaining.	
	Parts per 100,000.	Per Cent. of Total.	Parts per 100,000.	Per Cent. of Total.
Aldershot *b*. - -	5·195	98·95	0·0550	1·05
Coventry - - -	1·639	96·40	0·061	3·60
Aylesbury - - -	0·59	89·40	0·070	10·60
Aldershot *a*. - - -	1·543	88·2	0·207	11·8
Birmingham *a*. - -	0·840	80·0	0·210	20·0
Burnley - - -	0·895	74·6	0·305	25·4
Birmingham *b*. - -	0·390	37·1	0·660	62·9

On this table Aldershot on a dry day stands best, but not on a wet day. Coventry with its double system is next best. Aylesbury with precipitation alone is almost the same as Coventry with its double purification.

Perhaps this expression "on a dry day" is not quite fair, it is meant to show that in a case of an overflow there may be little or no purification, but there is generally some unless the flood be great.

RESIDUAL AMMONIA C.

—	Ammonia abstracted.		Ammonia remaining.	
	Parts per 100,000.	Per Cent. of Total.	Parts per 100,000.	Per Cent of Total.
Aldershot *b*. - -	11·36	100·0	0·00	0·00
Coventry - - -	5·081	99·8	0·009	0·2
Aylesbury - - -	4·269	88·0	0·581	12·0
Aldershot *a*. - - -	3·177	83·0	0·636	17·0
Birmingham *a*. - -	3·351	61·4	2·109	38·6
Burnley - - -	1·200	29·65	2·503	70·35
Birmingham *b*. - -	1·530	28·0	3·930	72·0

Aldershot (dry) is again the best; Coventry next; Aylesbury third.

The two chief ammonias in a sanitary point of view are the albuminoid and residual. They are therefore added here.

Table D.—Total Organic Ammonia, *i.e.*, Albuminoid and Residual; both Ammonias may be called "possible."

—	Ammonia abstracted.		Ammonia remaining.	
	Parts per 100,000.	Per Cent. of Total.	Parts per 100,000.	Per Cent. of Total.
Aldershot *b.* - -	16·555	99·65	0·055	0·35
Coventry - - -	6·720	98·97	0·070	1·03
Aylesbury - - -	4·859	88·20	0·651	11·80
Aldershot *a.* - - -	4·720	84·84	0·843	15·16
Birmingham *a.* - -	4·191	64·40	2·319	35·60
Burnley - - -	2·095	42·73	2·808	57·27
Birmingham *b.* - -	1·920	29·60	4·590	70·40

Table E.—Total Ammonia.

Aldershot *b.* - -	28·31	98·9	0·300	1·1
Coventry - - -	8·78	93·6	0·590	6·4
Aldershot *a.* - -	7·633	82·7	1·590	17·3
Aylesbury - - -	7·839	82·4	1·671	17·6
Birmingham *a.* - -	5·616	60·9	3·594	39·1
Burnley - - -	2·215	34·9	4·138	65·1
Birmingham *b.* - -	1·400	15·2	7·810	84·8

It is seen here that the lowest effluent for total ammonia is from the irrigation farm in dry weather. Coventry next. Aldershot (wet) and Aylesbury stand third nearly the same.

Nitric Acid.

—	Sewage.	Effluent. Parts in 100,000.
Aldershot *b.* - -	- -	9·23
Aylesbury - - -	None -	3·19
Aldershot *a.* - -	Traces -	2·79
Birmingham *b.* - -	None -	2·13
Coventry - - -	" -	1·22
Burnley - - -	- -	1·20
Birmingham *a.* - -	None -	1·19

Nitric acid shows the effect of oxidation on the organic matter, and here the great action of air and of a porous soil shows itself remarkably.

The best seems to be irrigation in dry weather when the land has full opportunity to act.

The use of precipitation has a decided advantage in wet weather as it raises the purity of the Coventry water above the Aldershot wet specimen. The precipitation method by alum, &c., at Aylesbury, is better in Tables B and C than in A. It is the best of the single processes in wet weather. Aldershot is the best of the single processes in dry. Coventry, the double process, is the best in wet weather. Those which are good in wet weather would probably show still better in dry if the specimens were taken frequently during the year. The precipitation processes, when alum or iron is used, have an advantage in wet weather, since the act of precipitation becomes an act of disinfection.

The effluent specimens were examined as to their tendency to putrefy. Those with lime changed most. Ammonia is in parts per 100,000.

——	Date.	Free Ammonia.	Albumenoid Ammonia.
Burnley, collected 16th June 1879.	June 20, 1879 -	1·33	0·305
	July 17, " -	1·92	0·23
	" 28, " -	1·92	0·30
	Sept. 4, " -	2·15	0·13
Birmingham, collected 23rd June 1879.	June 25, " -	3·222	0·662
	July 17, " -	4·20	0·336
	" 18, " -	4·15	0·336
	" 28, " -	3·90	0·324
Aldershot (wet) - Effluent C. - -	" 7, " -	0·44	0·144
	" 28, " -	0·364	0·130
	Sept. 4, " -	0·140	0·092
Aldershot, dry - -	" 16, " -	0·245	0·055
	Oct. 11, " -	0·240	0·058
Aylesbury, collected 2nd July 1879.	July 23, " -	0·96	0·067
	" 26, " -	1·00	0·06
	" 29, " -	0·96	0·06
	Sept. 4, " -	0·045	0·035

Birmingham (effluent) ammonia rose in 23 days from 3·222 to 4·2; then began to fall; Burnley in 27 days from 1·33 to 1·92; Aylesbury changed none in a week; Aldershot (dry) may be said not to have changed in 25 days.

The capacity to froth when shaken is a very useful mode of finding the comparative sewage matter rapidly. It may be said to have been absent in Aldershot (dry), Coventry and Aylesbury effluents. The clearness of the liquid is very important although a popular indicator. In the Coventry sample there were a few white floating particles; when these fell the water was clear and colourless. Three specimens—Aldershot (dry), Coventry and Aylesbury were without colour, when they had stood in a large colourless glass vessel.

The total solids are in this order in the effluents; the advantage is in being low, of course :—

	Parts per 100,000.
Aldershot average of three (wet) -	29·5
Aldershot dry - - - -	41·0
Burnley - - - -	54·0
Coventry - - - -	70·5
Aylesbury - - - -	89·5
Birmingham (*b*) - - -	100·5
Birmingham (*a*) - - -	112·5

During floods the volatile solids stand thus :—

Coventry - - - -	12·0
Aylesbury - - - -	13·5
Aldershot average of three (wet) -	13·8
Burnley - - - -	14·0
Birmingham (*a*) - - -	24·0
Birmingham (*b*) - - -	26·5

The chlorine has not been found the same in the effluent as in the sewage. This, I suppose, is owing to the effluent being from sewage of a time previous to that of the specimen of sewage.

The question has been asked which of these specimens is most suited for passing into a sewer. None of these effluents can be called sewer-water in the ordinary sense. The Birmingham stream froths readily, and is not pleasant to the eye. The Burnley water was pretty clear, would do well in appearance as a stream by itself, but caused a milky deposit in the river into which it fell, arising, we may suppose, from the free lime taking up some carbonic acid from the river water and precipitating carbonate of lime. The Coventry effluent went into a stream which was very impure, and it might, so far as appearance went, pass into a shallow mountain stream without being noticed. So of Aldershot and Aylesbury.

In every respect we may say that the best result has been obtained by irrigation when the weather is not so wet as to cause overflowing. Still it was not found highly successful after lime at Birmingham.

That the precipitation with alum or alum and iron compounds is next.

That in wet weather there is an advantage in precipitation, because the action is largely, if not wholly, independent of dilution.

That the lime process is valuable but not equal to the above precipitation processes.

I must repeat that in this report I allude only to the merits of the effluent. There is a good deal to be examined before pronouncing on the ultimate value of the processes, and of course a large proportion, if not all of the remaining reasoning, must be left for Mr. Rawlinson, for whose report this may be considered as a preparation.

I am, &c.

Manchester, 16th October 1879. R. ANGUS SMITH.

ANALYSES of SPECIMENS of WATERS from SEWAGE WORKS, expressed in Parts per 100,000.

SAMPLES from Burnley, collected 16th June 1879. (See Report by Dr. R. Angus Smith.)

—	Organic Carbon.	Free Ammonia.	Albumenoid Ammonia.	Residual Ammonia.	Total Ammonia.	Nitric Acid.	Sulphuric Acid.	Chlorine.	Mineral Solids.	Volatile Solids.	Total Solids.	Alkalinity as SO_3.	Hardness Before boiling.	Hardness After boiling.
Stream above sewage works -	0·476	0·025	0·024	0·075	0·124	0·50	3·26	1·28	17·0	3·0	20·0	7·50	10·81	7·78
Do. below ditto - -	0·987	0·236	0·070	0·219	0·525	0·56	4·12	1·90	18·5	6·5	25·0	9·00	12·64	8·22
Crude sewage - -	20·33	1·45	1·20	3·703	6·353	—	6·35	5·12	49·0	148·0	197·0	13·00	—	—
Effluent from sewage works -	3·737	1·33	0·305	2·503	4·138	1·20	7·38	5·06	40·0	14·0	54·0	13·00	20·92	17·16

SAMPLES from Birmingham, collected 23rd June 1879.

—	Organic Carbon.	Free Ammonia.	Albumenoid Ammonia.	Residual Ammonia.	Total Ammonia.	Nitric Acid.	Sulphuric Acid.	Chlorine.	Mineral Solids.	Volatile Solids.	Total Solids.	Alkalinity.	Hardness Before boiling.	Hardness After boiling.
Crude sewage - -	20·44	2·70	1·05	5·46	9·21	None	25·23	24·16	102·0	75·0	177·0	13·83	45·0	44·0
Effluent from settling tanks -	4·09	3·22	0·66	3·93	7·81	2·13	22·65	15·78	74·0	26·5	100·5	11·32	39·0	38·4
Effluent after irrigation -	2·303	1·275	0·21	2·109	3·594	1·19	18·19	11·46	88·5	24·0	112·5	37·77	66·8	29·22

Samples from Coventry, collected 24th June 1879.

—	Organic Carbon.	Free Ammonia.	Albumenoid Ammonia.	Residual Ammonia.	Total Ammonia.	Nitric Acid.	Sulphuric Acid.	Chlorine.	Mineral Solids.	Volatile Solids.	Total Solids.	Alkalinity.	Hardness	
													Before boiling.	After boiling.
Crude sewage - - -	11·33	2·58	1·700	5·09	9·370	None	11·33	6·85	59·0	31·0	90·0	25·35	32·80	9·85
Effluent from settling tanks (filtered).	1·418	2·40	0·245	0·511	3·156	None	7·21	6·30	55·0	16·0	71·0	22·34	37·15	15·62
Effluent after irrigation (drain out of order).	0·587	2·12	0·205	0·895	3·220	1·22	13·21	5·73	58·0	19·0	77·0	12·62	35·45	17·65

Sample from Coventry, collected 10th July 1879.

—	Organic Carbon.	Free Ammonia.	Albumenoid Ammonia.	Residual Ammonia.	Total Ammonia.	Nitric Acid.	Sulphuric Acid.	Chlorine.	Mineral Solids.	Volatile Solids.	Total Solids.	Alkalinity as SO_3.	Hardness	
													Before boiling.	After boiling.
Effluent after irrigation -	0·618	0·52	0·061	0·009	0·590	1·62	13·39	4·99	58·5	12·0	70·5	21·0	40·70	19·72

SAMPLES from Aldershot, collected 1st July 1879 (wet weather).

—	Organic Carbon.	Free Ammonia.	Albumenoid Ammonia.	Residual Ammonia.	Total Ammonia.	Nitric Acid.	Sulphuric Acid.	Chlorine.	Mineral Solids.	Volatile Solids.	Total Solids.	Alkalinity as SO_3.	Hardness Before boiling.	Hardness After boiling.
Crude sewage - - -	16.90	3·660	1·750	3·813	9·223	Traces	2·04	4·38	41·0	32·0	73·0	9·40	6·71	3·38
Effluent "A" from sewage farm	—	0·920	0·276	0·803	1·999	2·69	5·14	4·54	24·0	16·0	28·0	2·50	6·57	6·29
Effluent "B" from sewage farm	2·282	0·880	0·200	0·788	1·868	1·59	1·89	3·14	15·0	11·0	26·0	1·90	5·00	4·57
Effluent "C" from sewage farm	2·240	0·440	0·144	6·318	0·902	4·08	2·40	3·20	20·0	14·5	34·5	0·70	7·86	6·86
Collected 13th September 1879 (dry weather).														
River Blackwater - -	0·536	0·0108	0·03	0·0542	0·095	1·56	2·40	2·46	32·50	6·00	38·50	20·40	28·55	10·88
Crude sewage (camps) - -	43·76	12·00	5·25	11·36	28·61	—	4·29	12·08	48·0	93·0	141·0	16·40	11·70	4·43
Effluent from sewage farm -	0·970	0·245	0·055	—	0·286	9·23	4·48	15·53	24·5	16·5	41·0	Neutral	12·28	12·00

SAMPLES from Aylesbury, collected 2nd July 1879.

—	Organic Carbon.	Free Ammonia.	Albumenoid Ammonia.	Residual Ammonia.	Total Ammonia.	Nitric Acid.	Sulphuric Acid.	Chlorine.	Mineral Solids.	Volatile Solids.	Total Solids.	Alkalinity as SO_3.	Hardness Before boiling.	Hardness After boiling.
Crude sewage - - -	6·76	4·00	0·66	4·85	9·510	None	14·42	7·97	76·0	29·0	105·0	35·50	48·6	20·0
Effluent from 3rd settling tank -	0·633	1·02	0·07	0·581	1·671	3·19	30·21	5·44	76·0	13·5	89·5	11·20	66·40	37·1

No. VII.

Mechanical Aeration of Sewage, &c. Tables of Experiments.

In the experiments noted in the previous chapter we see how long and persistently the sewage matter, both with and without water, gives out ammonia, and we must add at the same time putrid, and therefore offensive, gases and vapours. The substances were preserved in vessels partially exposed to the air; that is, the air filled the vessel excepting a very small space occupied by the sewage matter, and fresh air occasionally allowed to enter. These carboys resembled the sewers themselves and similar confined places.

I now go to entirely different conditions, and give to the sewage matter abundance of air, examining the results. I must, however, add, that in the following experiments the amount of air supplied is greater than that usually given to sewage water in nature. It does, however, show qualitatively the result of aeration, and I look on the effect as a parallel to that which we see in the Clyde and elsewhere. The oxygen does its work, and the gases of putrefaction are to a large extent modified, and in time the action itself ceases.

The aeration experiments were all made by Dr. Storer's and Mr. Cranston's apparatus, lent me for the purpose.

It consists of an earthenware vessel containing 3·3 gallons; into this was put about 2½ gallons of liquid, or about 14 litres, having an archimedean screw in the centre, acting on a vertical shaft, and driving the water down a cylinder which does not reach to the bottom of the earthenware vessel, called the converter. Along with the water air is driven, and the mixed water and air rise up on the outer side of the centre cylinder ready to flow in again, and so continuously. The screw was driven by a gas engine of half-horse power.

Oxidation, Table I.

We see here the condition of the sewage before treatment. It is to be observed that it is not fresh organic matter, but matter which has undergone decomposition as well as oxidation. We see the first by the ammonia in solution, and the second by the nitric acid. The amount of free oxygen shows the source.

It is a curious fact, observed frequently, that one hour's aeration removes oxygen as well as carbonic acid, and there is a general coincidence of rise and fall with free exposure. The cause of this is not clear. It may be that the motion causes the oxygen to combine; there is also a slight rise of temperature, part of which may be due to friction and part to oxidation. After an hour's aeration the effect diminishes considerably, and oxygen tends to assume its original amount. The analyses were made a day after the aeration. There were many done immediately after aeration,—that is, after allowing the bubbles to

rise,—but the differences were too great to allow of any useful table, the gases coming probably at varying speeds from the liquid. It was decided, therefore, to wait for a day.

After standing for 16–18 days, we find that the oxygen of the non-aerated has greatly diminished, and the other shows itself in proportion to the amount of aeration. Aeration, therefore, has preserved not only from all sensible signs of putrefaction, but from such chemical action as these gases would indicate.

The nitrogen being 19·97 in one case is very high, and in another 22·7 c.c. in a litre; indeed all the nitrogens are very high, but I suppose the liberation of nitrogen in the experiments already given may account for this. Perhaps time was required to remove the nitrogen, or some may have been evolved during the extraction of the gases, but it was found frequently when there was no reason for believing in a mistake.

The carbonic acid, as we may suppose, is driven out by aeration, but gradually increases on standing.

The free ammonia diminishes uniformly with aeration, but more rapidly in the first hour, as we might expect. After standing there is no difference in the free ammonia of the specimens aerated for one and for more hours.

The albuminoid ammonia is not much changed in any of the aerated specimens, and this we might expect from the absence of putrefaction; some organic substance, however, has evidently decomposed, forming free ammonia. This organic substance is that which produces the residual ammonia—the nitrogenous matter not decomposed in the treatment for albuminoid ammonia. In the non-aerated the albuminoid ammonia has increased decidedly.

The nitric acid has in every instance disappeared, when kept long, and, no doubt, has given out nitrogen in conformity with previous experiments. This is an important point in the purification of rivers, and settles the question, do rivers purify? but not the time.

In this inquiry Wanklyn's process for ammonia and albuminoid ammonia was used, but I divide the nitrogenous matter into three parts, the ammonia free and saline as one, the albuminoid, and the residual. We do not follow the stages of decomposition when we estimate the total nitrogen only.

OXIDATION.—TABLE I.

DISSOLVED GASES, MANCHESTER SEWAGE:—1st GROUP of FOUR examined the DAY after AERATION.
„ 2nd „ 16–18 DAYS „

—	Oxygen, c. c. per Litre.	Nitrogen, c. c. per Litre.	CO_2, c. c. per Litre.	Total Gas, c. c. per Litre.	Oxygen, % of Total.	Nitrogen, % of Total.	CO_2, % of Total.	% O, O + N = 100.	% N, O + N = 100.	Ammonia and Nitrate. Free NH_3, per Million.	Albd. NH_3, per Million.	HNO_3, per Million.
Manchester Sewage, from Miller's Lane, received 12/1/81:—												
Before treatment .... Examined 13/1/81 -	4·00	18·24	21·51	43·75	9·22	41·59	49·19	18·28	81·72	48·0	10·8	4·07
Aerated 1 hour, 12/1/81 .... „ „ -	2·71	19·03	12·86	34·60	7·69	54·09	38·22	14·76	85·24	34·0	—	4·63
„ 2 hours, 13/1/81 .... „ 15/1/81 -	4·42	18·15	18·12	40·69	10·88	44·57	44·55	19·6	80·4	31·68	10·6	3·71
„ 4 hours „ .... „ „ -	3·94	18·18	21·37	43·49	9·00	42·20	48·80	17·59	82·41	25·6	10·4	5·19
Manchester Sewage, from Miller's Lane, received 12/1/81:—												
Before treatment .... Examined 31/1/81 -	1·88	20·80	31·73	54·41	3·45	41·67	55·88	8·27	91·73	32·0	13·4	0·00
Aerated 1 hour, 12/1/81 .... „ „ -	1·94	19·97	—	21·94	8·84	91·02	—	8·86	91·14	32·0	8·40	0·00
„ 2 hours, 13/1/81 .... „ „ -	2·76	22·70	19·4	44·86	6·15	50·61	43·24	10·84	89·16	33·0	7·70	0·00
„ 4 hours „ .... „ „	3·48	19·15	30·40	53·03	6·57	36·12	57·31	15·4	84·6	33·0	8·52	0·00

Table II.

Glasgow Sewage.

After half an hour's oxidation the carbonic acid fell as before. The oxygen was very low at first, and rose but only a little. The addition of lime has lessened both the carbonic acid and oxygen. This in part explains the increase of nitrates when lime is used. There seems no increase of nitrates by aeration with the apparatus alone, but there is some formed after 22 days.

The free ammonia diminishes by the use of agitation, but increases by standing.

TABLE II.

Dissolved Gases, Glasgow Sewage partly with Lime:—1st Group of Four examined the Day after Aeration.
" 2nd " Two " 22 Days "

—		Oxygen, c. c. per Litre.	Nitrogen, c. c. per Litre.	CO_2, c. c. per Litre.	Total Gas, c. c. per Litre.	Oxygen, % of Total.	Nitrogen, % of Total.	CO_2, % of Total.	% Oxygen, O + N = 100.	% Nitrogen, O + N = 100.	Ammonia and Nitrate. Free NH_3, per Million.	Albd. NH_3.	HNO_3.
Glasgow Sewage, received 8/2/81:—													
Before treatment	Examined 9/2/81 -	0 44	12·16	30·10	42·70	1·03	28·47	70·50	3·5	96·5	91·9	—	—
Aerated ½ hour alone, 9/2/81	" 10/2/81 -	0·71	13·69	20·10	34·41	2·04	39·64	58·32	4·9	95·1	91·9	—	—
" " and ½ hour with lime.	" "	0·12	17·12	0·02	17·26	0·70	99·19	0·11	0·71	99·19	88·0	—	—
" " and 1 hour with lime.	" "	0·06	18·23	4·40	22·69	0·25	80·36	19·39	0·30	99·7	85·0	—	—
Glasgow Sewage, received 8/2/81:—													
Before treatment	Examined 4/3/81 -	1·39	19·21	97·88	118·48	1·17	16·21	82·62	6·77	93 23	114·0	7·34	2·96
Aerated ½ hour alone, and 1 hour with lime, 9/2/81.	" "	1·91	12·94	39·47	54·32	3·52	23·82	72·66	12·87	87·13	86·4	13·6	9·78
Glasgow Sewage, received 8/2/81:—													
Aerated without, and then with, lime...	Examined 4/3/81 -	1·38	18·44	0·15	19·97	6·92	92·34	0·74	6·97	93·03	66·0	7·0	7·41

TABLE III.

Dissolved Gases, Glasgow Sewage.

—		Oxygen, c. c. per Litre.	Nitrogen, c. c. per Litre.	CO_2, c. c. per Litre.	Total Gas, c. c. per Litre.	Oxygen, % of Total.	Nitrogen, % of Total.	CO_2, % of Total.	% Oxygen, O + N = 100.	% Nitrogen, O + N = 100.	Ammonia. Free NH_3, per Million.
Glasgow Sewage, received 5/2/81:—											
Before treatment	Examined 5/2/81 -	6·41	19·15	34·68	60·24	10·64	31·78	57·58	25·09	74·91	87·29
Aerated 1½ hours, 6/2/81, without air tubes	„ 7/2/81 -	4·75	15·86	45·04	65·65	7·23	24·16	68·61	23·04	76·96	87·00
„ „ and ½ hour with 12 gr. CaO, 6/2/81.	„ „	2·40	16·51	0·40	19·31	12·4	85·5	2·1	12·66	87·34	82·90
„ „ and 1 hour with 12 gr. CaO, 6/2/81.	„ „	2·06	18·18	0·75	20·99	9·81	86·58	3·61	10·2	89·8	80·7
Glasgow Sewage, received 5/2/81:—											
Before treatment	Examined 3/3/81 -	0·66	14·24	0·04	14·94	4·42	95·31	0·27	4·43	95·57	108·0
Aerated 1½ hours alone, and 1½ hours with lime.	„ 4/3/81 -	4·58	15·40	0·04	20·02	22·89	76·93	0·18	22·93	77·07	114·0

Summary of Experiments, Aeration of Sewage.

In all cases putrefaction is delayed by aeration. The oxygen recovers itself in the aerated specimens better than in the non-aerated. Nitrates are formed more readily in the aerated than in the non-aerated specimens.

Ammonia is lost by agitation, but specially by the previous addition of lime. The amount of lime added was ·171 gr. per litre, or 12 grains to the gallon.

TABLE IV.

The experiments were made with water containing 10 cub. cent. of putrid blood to 15 litres.

They show a diminution of oxygen and of carbonic acid by agitation; also an increase of nitrates.

The peculiarities came out more strongly here than with the sewage.

The diminution of oxygen is not observed so much in the aerated as in the non-aerated.

The oxygens rise and fall very irregularly; this may come from changes of temperature.

The nitrates always rise up to a certain point, and then begin to fall.

It appears as if the putrid matter were able to contain nitrates to a certain extent before the action which destroys them both commences. This also depends on temperature.

TABLE IV.

Dissolved Gases. Putrid Blood. Effect of Time and Aeration.

Standing various Lengths of Time.

—	Oxygen, c. c. per Litre.	Nitrogen, c. c. per Litre.	CO_2, c. c. per Litre.	Total Gas, c. c. per Litre.	Oxygen, % of Total.	Nitrogen, % of Total.	CO_2, % of Total.	% O, O + N = 100.	% N, O + N = 100.	Ammonia and Nitrate. Free NH_3, per Million.	Albd. NH_3, per Million.	HNO_3, per Million.
10 c. c. putrid blood + 15 litres Manchester water, mixed 28/12/80:—												
Not treated .... Examined 29/12/80 -	—	—	—	—	26·33	62·07	11·60	29·8	70·2	5·5	6·00	0·00
„ .... „ 3/1/81 -	1·84	17·10	7·34	26·28	7·01	65·05	27·94	9·74	90·26	5·8	5·80	—
„ .... „ 14/1/81 -	4·80	17·5	3·50	25·8	18·6	67·8	13·60	21·53	78·47	—	—	—
„ .... „ 28/2/81 -	2·49	19·04	4·05	25·58	9·66	74·56	15·78	11·47	88·53	10·8	2·85	1·8
Putrid Blood aerated for one hour. Effect of Time.												
10 c. c. putrid blood + 15 litres Manchester water, mixed 28/12/80:—												
Aerated 1 hour, 28/12/80 .... Examined 29/12/80 -	7·56	15·61	3·91	27·08	26·76	57·74	15·50	32·53	67·47	6·3	6·3	0·00
„ „ .... „ 3/1/81 -	3·43	14·46	5·49	23·38	14·65	61·87	23·48	19·16	80·84	7·2	4·8	—
„ „ .... „ 13/1/81 -	1·79	15·85	2·23	19·87	9·01	79·77	11·22	10·15	89·85	5·8	6·86	7·84
„ „ .... „ 28/2/81 -	4·03	13·21	1·88	19·12	22·19	68·12	9·69	24·57	75·43	8·0	3·84	3·50
10 c. c. putrid blood + 15 litres water, mixed 28/12/80:—												
Aerated 2 hours, 28/12/80 .... Examined 29/12/80 -	3·33	16·79	1·70	21·82	15·28	76·94	7·78	16·56	83·44	6·46	6·08	0·00
„ „ .... „ 3/1/81 -	3·15	15·77	2·85	21·77	14·48	72·44	13·08	16·60	83·40	6·40	7·00	7·41
„ „ .... „ 13/1/81 -	2·31	18·50	3·28	24·09	9·59	76·78	13·63	11·11	88·89	7·20	6·75	7·84
„ „ .... „ 28/2/81 -	5·27	12·73	2·12	20·12	26·20	63·25	10·55	29·29	70·71	7·00	4·80	3·15
10 c. c. putrid blood + 15 litres water, mixed 28/12/80:—												
Aerated 3 hours, 30/12/80 .... Examined 31/12/80 -	5·21	35·78	5·06	46·05	11·31	77·70	10·99	12·71	87·29	6·93	6·05	0·15
„ „ .... „ 5/1/81 -	4·06	17·30	4·54	25·90	15·67	66·76	17·57	19·00	81·00	5·80	6·4	16·31
„ „ .... „ 28/2/81 -	6·14	12·48	6·23	24·85	24·71	50·23	25·06	32·97	67·03	11·10	4·48	5·19
10 c. c. putrid blood + 15 litres water, mixed 30/12/80:—												
Aerated 4 hours, 30/12/80 .... Examined 30/12/80 -	5·00	11·66	3·36	20·02	24·96	58·25	16·79	30·0	70·00	6·00	6·00	2·52
„ „ .... „ 5/1/81 -	1·90	15·00	4·15	21·05	9·04	71·23	19·73	11·26	88·74	4·80	4·80	11·12
„ „ .... „ 14/1/81 -	3·03	13·55	4·59	21·17	14·32	64·04	21·64	18·28	81·72	—	—	—
„ „ .... „ 28/2/80 -	4·95	14·94	1·61	21·50	22·98	69·52	7·50	24·84	75·16	4·70	3·76	5·22

TABLE V.

Dissolved Gases. White of Egg. Effect of Time and Aeration.

—	Oxygen, c. c. per Litre.	Nitrogen, c. c. per Litre.	CO_2, c. c. per Litre.	Total Gas, c. c. per Litre.	Oxygen, °/o of Total.	Nitrogen, °/o of Total.	CO_2, °/o of Total.	°/o Oxygen, O + N = 100.	°/o Nitrogen, O + N = 100.	Ammonia and Nitrate. Free NH_3, per Million.	Albd. NH_3, per Million.	HNO_3, per Million.
White of one egg in 15 litres water, mixed 31/12/80:—												
Not treated .... Examined 3/1/81 -	4·44	13·56	0·49	18·49	24·04	73·36	2·60	24·68	75·32	0·80	15·12	5·18
„ .... „ 6/1/81 -	2·67	20·33	2·45	25·45	10·48	79·88	9·64	11·69	88·31	—	—	—
„ .... „ 4/3/81 -	2·77	14·00	4·96	21·73	12·78	64·38	22·84	16·69	83·31	8·08	10·40	2·70
White of egg in 15 litres water, mixed 31/12/80:—												
Aerated 1 hour, 31/12/80 .... Examined 3/1/81 -	3·86	10·83	0·61	15·30	25·25	70·73	4·02	26·31	73·69	0·84	17·60	5·92
„ „ .... „ 6/1/81 -	4·40	20·74	4·30	29·44	14·90	70·46	14·64	17·49	82·51	0·90	16·50	20·01
„ „ .... „ 1/3/81 -	4·94	19·00	7·06	31·00	15·92	61·29	22·79	20·62	79·38	5·70	6·30	2·00
White of egg in 15 litres water, mixed 31/12/80:—												
Aerated 4 hours, 31/12/80 .... Examined 3/1/81 -	3·34	20·50	0·24	24·08	13·89	85·11	1·00	14·01	85·99	0·90	12·00	0·00
„ „ .... „ 1/3/81 -	4·97	16·76	1·70	23·43	21·20	71.52	7·28	22·87	77·13	2·12	9·40	2·89

TABLE VI.

DISSOLVED GASES. YOLK OF EGG. EFFECT OF TIME AND AERATION.

—	Oxygen, c. c. per Litre.	Nitrogen, c. c. per Litre.	CO_2, c. c. per Litre.	Total Gas, c. c. per Litre.	Oxygen, % of Total.	Nitrogen, % of Total.	CO_2, % of Total.	% Oxygen, O + N = 100.	% Nitrogen, O + N = 100.	Ammonia and Nitrate. Free NH_3, per Million.	Albd. NH_3, per Million.	HNO_3, per Million.
Yolk of one egg in 15 litres water, mixed 3/1/81:—												
Not Treated .... Examined 4/1/81 -	2·51	20·60	1·90	25·01	10·04	82·36	7·60	10·86	89·14	1·25	12·00	—
„ .... „ 7/1/81 -	0·65	16·18	2·89	19·72	3·28	82·09	14·63	3·85	96·15	0·48	18·00	—
.... „ 3/3/81 -	0·84	9·26	4·20	14·30	5·87	64·75	29·38	8·32	91·68	1·12	11·25	2·30
Yolk of one egg in 15 litres water, mixed 3/1/81:—												
Aerated 1 hour, 3/1/81 .... Examined 4/1/81 -	3·76	18·75	2·64	25·15	14·94	74·58	10·48	16·69	83·31	0·60	12·50	—
„ „ .... „ 7/1/81 -	1·58	15·06	1·79	18·43	8·55	81·74	9·71	9·47	90·53	8·08	13·30	7·86
„ „ .... „ 3/3/81 -	2·12	15·35	4·82	22·29	9·49	68·86	21·65	12·12	87·88	0·96	11·10	3·59

No. VIII.

Connection of this Work with recent Microscopic Inquiries.

It may be interesting to connect this subject with the progress of microscopic inquiry. After writing the opinion on the action of the air, I made many examinations of aerated sewage, and found that the act of aeration prevented putrefaction. It was my intention to examine the matter microscopically; and, indeed, I did so, but not with that fullness which a professed microscopist attains. I am therefore glad to allow this part of the subject to pass into other hands, so far as sewage is concerned, remarking that the chemical change is most decided. An hour's aeration will enable sewage water to keep without putrefaction from two to three weeks in weather ranging from the beginning of July 1880 in Glasgow, where experiments were first made with Storer and Cranston's apparatus, till the end of spring 1881 in Manchester.

My idea was to kill, by the use of air, the germs of disease and of putrefaction, whatever they might be, judging this possible simply from the fact that they seemed to be killed when they passed from sewers into rivers. Still it seemed to me that it would be better if putrefaction were allowed its full action first, so that many organic substances should be decomposed, and some living organisms themselves broken up into gases or into intermediate products, when afterwards the oxygen would purify the solution. This is a plan that may be adopted systematically in some places, as I believe it is adopted practically, but without intention, in many places. The action in the sewer rivers is partly this; and when there is little water, that is, when there is a strong solution of sewage, this is probably the chief action. The oxidation takes place very rapidly after putrefaction. (On this point I have only general observation, not measured results.) As we seldom can allow the water to stand long enough to undergo complete putrefaction, it comes from the sewers into the rivers in a condition which, so far as I know, has not been characterised microscopically with a knowledge up to the latest date. I am therefore speaking somewhat vaguely when I say that we may take it for granted that the minute organisms causing disease have not been acted on sufficiently to be destroyed. It would be interesting to know at what stage they are destroyed. The mixture of the sewage water with river water will produce an act of oxidation to a certain extent, and will, in cases where there is water enough, produce an act of purification so far, but a further flow will increase the oxidation. In the Clyde and the Irwell (as in the Thames before the new sewage system was adopted) the action of putrefaction is decided, but it is limited by the struggle with oxidation. A part of the river becomes a reservoir for putrefaction, although probably not to its utmost, and the lower part a place for oxidation. For this reason it is suitable to have the first part confined, so as to allow the putrefaction full force, and after this

to have the water spread as much as possible to allow of fullest oxidation. A fair example of this is given in the action in the Clyde above Dumbarton as putrefactive, then down to Greenock as oxidizing; and if by no means satisfactory, it is so far good and nature's method.

This is entirely regardless of the comfort of the inhabitants, who may object to the part of the river being devoted to purification by putrefaction. That, however, brings in another subject. For irrigation purposes *solely*, rapid transference is best.

To return again to the effect of oxidation, I wish to introduce an extract from two papers; and, first, that already quoted, Chem. News, 1865, p. 304.

"*On the examination of Water for Organic Matter.*

"The gases of pure water contain 34 per cent. of oxygen.

"Dalton found cistern water almost deprived of its oxygen, and I have found every per-centage of oxygen, from 34 downwards. I go further into this point in my chapter on water, which I hope to bring out soon. Meantime, I may say that the examination for oxygen is a very important one.

"The loss of the oxygen with peaty matter and no vegetation indicates, as already said, the formation of carbonic or a bitter acid. The loss of oxygen with evolution of sulphuretted hydrogen indicates putrefaction. But there are two conditions which externally resemble each other very much,—the growth of vegetable matter with diminished oxygen, and the growth of vegetable matter with excess of oxygen. Water in the first of these conditions may contain, as I imagine, the most dangerous ingredients. Germs of all kinds may exist in such waters,—we do not know to what extent; and as we are very ignorant on the subject, it is well to be alarmed at the conditions until we have examined them and made distinctions."

I add, perhaps too cautiously, but still believing in the power of oxidation, even when vegetable matter was growing in it:—
"We do not know much about the second of these two (*i.e.* with excess of oxygen), and if I think it is less dangerous it is perhaps more from a prejudice in favour of the abundance of vital air, and of those hill waters which do not contain bitter peat."

So far as this purification by air is concerned, it is interesting to see that it is the right track, and to be able to look at the researches of Pasteur and of Dr. Ogston as confirming the views, if indeed there was any need of confirmation of the fact that air purified. Yes, there was need, as there have been questions as to organisms on the hills acting with all their poisoning vigour after being brought down by rivers. It was my belief at one time that the effect of dilution was the purifier, but now that may be supplemented by the effect of oxygen preventing putrefaction as proved here, and by weakening the action of the germs, at least of some diseases, as shown by Pasteur in his researches on the chicken cholera, and by Dr. Ogston on the micro-organisms in pus.

The words of Pasteur may be given here, as introduced into the "Chemical News," 22nd April 1881:—

"On the Attenuation of the Virus of Chicken Cholera, by L. Pasteur.

"Now that we have arrived at this point, a question presents itself which relates to the cause of the attenuation of virulence.

"The cultivations of our virus must take place in contact with air, because our virus is aerobian, and, without air, its development becomes impossible. We are then naturally led to ask whether the attenuation of the virus is not due to contact with the oxygen of air? Would it not be possible that the small organism which constitutes the virus, when left in contact with the oxygen of pure air, in the medium of cultivation in which it has developed, may have been modified, and the change remains permanent, even after the organism has been withdrawn from the modifying influence? We may also inquire whether some chemical principle in the atmosphere, other than oxygen, does not intervene in this phenomenon, the singularity of which almost justifies my hypothesis.

"It is easy to understand that the solution of this problem, in case it depends on our first hypothesis, that the phenomenon is due to the oxygen in the atmosphere, may be tried by experiment. If oxygen is in reality the cause of the attenuation of virulence, we may have, to a certain degree, a proof of it by noting the effect of suppressing it.

"To test this, let us conduct our cultivations in the following manner:—We may take a certain quantity of our chicken broth and place in it the most virulent virus, and fill with it a series of glass tubes up to two-thirds, three-quarters, &c. of their volumes. These tubes may then be closed over the lamp. By the presence of the small quantity of air left above the liquid the development of the virus may be started, which is ascertained by the increasing turbidity of the liquid. The development of the cultivation gradually absorbs all the oxygen contained in the tube. The turbidity then diminishes, the growth is deposited on the sides of the tube, and the liquid becomes limpid. This takes places generally in two or three days. The microscopic organism is then deprived of oxygen, and will remain in this condition as long as the tube is not opened. What will become of its virulence? To be sure of our results we will have prepared a great number of such tubes and an equal number of flasks, which last will continue to be left in contact with pure air. We have already spoken of what becomes of cultivations carried on in presence of air. We know that they experience a progressive attenuation of their virulence, and we will not return to this subject. Let us now only pay attention to the cultivations in closed tubes. Let us open them—one after an interval of a month, another after three months, and so on until we open one that has stood ten months. I have

not gone any further at the present time. It is a remarkable circumstance that the virulence in all these cases is of the same degree as that of the liquid which served to fill up the tubes. As to the cultivation exposed to the air, they are found either dead or in a condition of feebler virulence.

"The question we have proposed is then solved: it is the oxygen of the air which attenuates and extinguishes the virulence.

"To all appearances we have here what is more than an isolated fact. We must have reached to a general principle. We may suppose that an action which is inherent to atmospheric oxygen, an agent present everywhere, has the same influence on other viruses. At any rate it is worthy of interest that possibly a general cause of attenuation exists dependent on an agent which is in a manner cosmical. Can we not suppose even now that it is to this cause that we can attribute in the present, as in the past, the limits set to great epidemics.

"The facts which I have had the honour to communicate to the Academy suggest many proximate and remote inductions. From all these I must hold back with reserve. I will not feel authorised to present them to the public unless I make them pass into the domain of demonstrated truths."

Also from Dr. Alex. Ogston:—

From a "Report upon Micro-organisms in Surgical Diseases," by Alexr. Ogston, M.D.—Brit. Med. Jour., 12th March 1881.

"The results, so far as has been gone, may be summed up as follows:—

"Cold abscesses contain no micro-organisms, and their pus is harmless.

"Acute and pyæmic abscesses always contain micrococci.

"Pus whose micrococci have been killed by carbolic acid or high temperature is harmless.

"Pus containing micrococci is resisted by animals if the dose be minute, or if it be injected into the peritoneal cavity.

"Doses of one or two minims injected into the sub-cutaneous tissue may cause death by blood-poisoning, or may cause sphacelus of the site of the injection, or may be resisted by an unusually insusceptible animal.

"As a general rule such doses produce acute inflammation, accompanied by blood-poisoning and ending in abscess.

"The third part, upon micrococci in wounds and suppurations, is summed up as follows:—

"Suppurating wounds contain micrococci, whose numbers and activity are proportionate to the intensity of the suppuration.

"Listerian dressings prevent micro-organisms from gaining access to wounds.

"Micrococci in wounds withstand most antiseptic applications.

"Where no micrococci are present in wounds, no pus is produced; the discharge is serous.

"Micrococci exist wherever pus occurs, save in chronic suppurations, such as cold abscess, chronic acne vulgaris (?), &c. Micrococci in man produce the same varying effects as in animals; they may produce blood-poisoning without suppuration, they may cause suppuration, or they may be resisted by strong individuals under favouring circumstances. Lastly, there are possibly micrococci that do not produce suppuration."

An account of numerous cultivation experiments is given, and the certain opinion is expressed that the cultivation must go on in absence of air, *i.e.* air is hurtful to the cultivation of the micrococci. The most successful method employed was to inject the seed fluid to the end of an egg opposite to a very small puncture made to admit a hollow needle. Antiseptic precautions were taken to exclude the action of germs in the air.

"To sum up, micrococci do not produce putrefaction. They develope best when removed from the atmosphere. The preceding facts prove that they are able, under suitable circumstances, to give rise to blood-poisoning, to acute inflammation, and to suppuration."

The experiments described in this report show that aeration delays putrefaction. If it does not kill the germs or organisms which produce putrefaction, it weakens them, as in the case of chicken cholera. It is possible that they may die in the oxygen, and the liquid may be again supplied with them.

A curious question arises then: What is the value of a process of oxidation which does not kill the germs of putrefaction; because, if they are not killed, what proof have we that the germs of diseases are not killed? We have no proof; but we are told by Pasteur that in certain cases at least the germs of disease are made innocent by the action of air; and I find as a distinct fact that the germs of putrefaction are also so weakened that they produce no effect until after considerable time. If the germs of all diseases are affected as the germs of chicken cholera and putrefaction are, then we must look to the aeration as a cure for a certain time. This time being long and measured by weeks, the water or sewage treated can in almost all cases be far removed, and sent to places where its impurities will be without effect.

The proposal quoted from my previous papers to examine the growth of the organisms in water was not carried out by me, but I am glad to have been in the right track so long ago, and to have been so also with the inquiries as to oxidation. The results obtained by Koch and also by Klebs must receive the attention of chemists. It does not appear that even if we kill all the germs in any process that much advantage is gained if they are so readily producible from neighbouring sources. The discussion whether those which are most common in smaller numbers, and are in constant supply, can by some peculiar change of condition not visible to us become so abundant as by

their very bulk to be deadly, or by their character to be active, virulent, and equally destructive to higher animal life, is one which must greatly interest chemists as well as biologists. As chemists we can only exhibit the inorganic phenomena so far; we have no test for vitality. The advice I gave so long ago has not been sufficiently taken by myself, but Koch has made it easier to take, and we must not forget the results. At the same time, as chemists we must not forget that chemical tests are not exhausted, and the two inquiries must go on until they blend into one, as they must ultimately do.

These researches do not prove to us that the germs spoken of are destroyed by oxygen; they become weak, and this weakness increases to absolute ineffectiveness, and so far we are guarded; and they may be supposed also from their weakness to increase less rapidly, or to cease to play a prominent part, but ready to begin again. Analogy, however, would lead us to believe in complete annihilation of the first series in the case of those that produce putrefaction, so that they may make room for their successors. The relation of the succeeding to the first is not known to me at least, and I judge simply from analogy that the first organisms will be destroyed with the mass of the organic matter which is destroyed. The destruction is so great in the case of putrefaction that we see the bubbles rising before us rapidly. The gases given out were found to be carbonic acid, hydrogen, carbonic oxide, carburetted hydrogen, nitrogen, sulphuretted hydrogen.

Still there is a limit to the proportion of organic matter destroyed by putrefaction, and I suppose oxygen to be the body which comes and concludes the process. There is, however, an oxidation going on slowly in sewage before putrefaction, but it is not a very rapid one, and what time is required to destroy the several classes of organisms has not been made out. I see no reason as yet for Pasteur's hypothetical influence other than oxygen.

When Dr. Storer came to me with a proposal to use his apparatus for aerating sewage, we had not the investigations of Pasteur to go upon, but I was very glad to have the opportunity of using the means put into my hand, Dr. Storer's apparatus, as the time for considering the subject was come.

To the opinions and facts already given we must add the remarkable observations recorded in the Royal Agricultural Society's Journal, No. XXXIII, Part 1, 1881, by Dr. W. S. Greenwood.

It seems clearly proved there that sewage that has undergone no putrefaction or sufficient oxidation is a very destructive agent when it contains the débris of diseased action in the human body, in some if not all cases. It seems to follow as a natural conclusion that as disease has not been observed to any very decided extent as following the use of sewage irrigation, that the putrefaction and oxidation are in ordinary cases sufficient. But there are some differences of opinion, and it is pro-

bable that these processes of destruction and purification, in cases where the sewage has been injurious, have been interrupted too rapidly by the rapid transfer of the sewage to the soil. On this point we must refer to the remarkable inquiry by Dr. Greenwood. At a mill near Bingley, woolsorters' disease and malignant pustules had broken out amongst those who worked with mohair coming from Van. To disinfect the wool it was exposed to the air on a field. In a few days a cow died in a field which received the village sewage, and next month cattle and sheep were attacked by anthrax. In a series of experiments carefully made it was abundantly proved that the disease had come from the wool,—which, however, seemed to have been roughly torn, let us hope, from dead animals, as some of the skin and flesh was at times found attached.

In relation to this report on impure wool, I may mention a circumstance elsewhere mentioned, as it occurred many years ago. I was rather disgusted on entering into a room in a large paper-works where rags were sorted. These rags came from all the miserable wretches that lived or died in unwholesome dens, prisons, workhouses, and hospitals on the continent, and seemed to call up every variety of human bodily misery lingering in our civilisation. What diseases might not be there, and must have been there. In this room dust was flying about, and a number of young people, about 20 years of age, were working diligently there. I certainly never had seen more healthy looking specimens of young women. They were much beyond the average in bulk, their cheeks were ruddy, and their complexions remarkably good, different decidedly from other women in the neighbourhood. I asked if none of them were ever poisoned: no such thing was said to be known. I asked the owner to weigh them, but he never did so. I have often considered this case, and every time I came to the conclusion that the original substances had undergone a transformation, and the germs of disease had been destroyed by an act, if not of putrefaction, of at least some analogous chemico-organic change. This first showed me the value of putrefaction as a purifying agent.

I may add here that I had attempted by the use of fermentation to estimate the amount of vitalized matter in the air, and I give one attempt here from the 10th Annual Report, pp. 42 and 43.

"Some Hidden Qualities of Town Air.

"Some years ago I made inquiries into the effect of various substances in preventing putrefaction; the effect was measured in one set of trials by the amount of sulphuretted hydrogen produced, and in another set by the amount of gases of decomposition evolved. Lately I made another series, with the view of finding if there were any bodies in the atmosphere of large towns which prevented decomposition, the opinion being that the sulphurous gases must have this effect. I did not find that putrefaction was a satisfactory method of trial, and I trusted to

fermentation of sugar as one more under our command. The air of the town was used first, that is, a certain quantity of air was washed with pure water, and a fixed quantity of sugar and yeast added. At the same time there was a control experiment made, lest the yeast should be peculiar. This was done simply by using the same amount of yeast and sugar in pure water, without adding any air washing. There was no mode, however, employed of preventing ordinary contact of the air.

"The results of these experiments are very irregular, as one might suppose when dealing with such substances as yeast. Sometimes the amount of carbonic acid obtained was almost nothing, and at other times, apparently with the same quality of substance, there would be disengaged a large amount. It was needful, therefore, to make numerous experiments, satisfied that absolute exactitude could not otherwise be gained, if it even then could. The results, however, are not without interest if we take the averages, because in them we see a uniformity which it is impossible to see in the list of apparently struggling individual experiments.

"These trials were made at various times, occupying a portion of every month for two years. It seemed to me that nothing would come of them, and that much time was lost. However, I did venture to look the whole in the face lately, and summed them up, bringing out the averages. It is apparently true that the air of a town influences fermentation in sugar to a certain extent."

The researches of Dr. Koch, however, have obtained results far superior, and by using a part of his process I am obtaining very promising results, to be spoken of later.

Having now given some of the principal points connected with the idea of aerating sewage, I may make some further investigation into the result. What advantage would it be to any city to send down its sewage into a river in a condition in which it did not putrefy, if it were to have an appearance of impurity as great as ever? I think this would be an advantage, but not a sufficient one. We demand more. Indeed, the appearance is quite as much a matter to be considered as any other point. Perhaps we may say that it is the chief point. We have not proved any disease to occur from the sewage below Glasgow or Manchester, although I see that some one has observed a peculiarly poisonous centiped in the mud opposite Liverpool, and fears, probably too well founded, are rising on the Clyde where shores are left bare. The appearance of a river is, to say the least, a prominent point; next, the fish question is an important one; and although sewage is an excellent feeder of fish, these do not enter the places where sewage is very strong, and, I believe, never at all where there is putrefaction going on. We do not effect enough by removing the tendency to putrefy. We may then ask, what more is to be done?

A very common plan is to allow the sewage to pass into tanks and deposit. This generally brings on purification by putrefaction, and of course would receive favour if it were thorough enough,—which it seldom, if ever, is. In most cases there is not ground enough for it; and although some towns take

room enough by converting the rivers into putrefying tanks, and so purifying the water, the result has the objection already mentioned. This certainly has the advantage of being well tried. I might have mentioned. as an argument in favour of putrefaction and the destruction of diseases in rivers, that the Thames water not along ago was considered the best of all water on ships, after it had stood and putrefied in the barrels on board. I am therefore on safe ground. Still it is desired that the water be cleared, and it is cleared at present very slowly by putrefaction and subsequent subsidence or filtration in its own bed.

For sewage filtration unaided has been given up, but filtration with lime is a possible process.

The use of lime has now been long tried, and it has been shown to pcssess many good qualities. It clears the sewage with great rapidity to a certain extent. But I need not describe its action, as this has been done so well before, and especially by Dr. Wallace, of Glasgow, who has made a special study of the subject. It may be even asked, what advantage can we obtain by any aeration if lime is used?

It is agreed that the effluent from lime is still liable to putrefaction, although this action is postponed for a time and diminished also. Dr. Wallace finds that if the sewage water of Glasgow is allowed to mix with twelve times its bulk of river water, the result will be entire freedom from further smell or putrefaction. It has, among other results, been oxidized. By aeration, then, we seem to do that something for a time which twelve times its bulk of water does to the sewage permanently. The absence of putrefaction after aeration, even with the solid remaining in the water, is a very great result; still I am unable to decide on its ultimate value from present results.

Lime, then, does not disinfect in such a way as to prevent putrefaction as long as aeration does, but it clears the liquid much more thoroughly, and if the effluent is removed the putrefaction resulting cannot be equal to that which would take place in the aerated sewage after a certain time.

This seems to lead to another point, namely, is it not best, then, to use both processes—the lime and the aeration? The lime to clear, and the aeration to delay putrefaction, until the water flowed out of the reach of danger. It is probable that in this case none would take place whatever in any of the circumstances usually found at towns.

The results here are given of a great many experiments, but they are all laboratory experiments, we must remember. I have, however, seen enough of lime precipitation to make me believe that something more would not be a disadvantage.

This account does not contradict anything already said of the great value of the use of alum and iron salts, and it is thought well to append the account previously given, 1879. The matter of expense must be settled by others.

No. IX.

Extraction of Ammonia.

I have not at all considered independently the expense of aerating in this manner a million gallons, but I am assured that the apparatus is not at all likely to be too expensive. It has been considered that one hour's agitation will be enough. This has been variously calculated for expense. I shall not give my calculation. The amount arrived at is much higher than that obtained by Messrs. Storer, but I must yield to their greater experience.

When sewage is aerated, and left with the solid matter in it, there is, of course, abundant room for a new succession of putrefactive material, and it is necessary to remove that rapidly by precipitation or by filtration. These methods may both be useful; namely, precipitation, so as to allow the deposit to leave a considerable amount of clean water above. After this filtration may be used for collecting the deposit, if it is true that the improvements in filters is as great as I hear of. I have read and been told of several inventions in this direction which seem to me of great value, but I have not entered practically on a study of them. It was found, however, that ammonia came off more readily when the sewage was not filtered.

This subject has baffled all engineers. Sewage has caused expense, and it has failed to produce profit in cases which cannot be called exceptional. It is not proposed to describe the causes, but one certainly is pre-eminent,—the great bulk of water now used for supplying towns. And this cause allies itself to another, namely, the great mass of water as rain, which in some parts of the country weakens the sewage in its flow or in the fields already drenched. The amount of ammonia, as we have long known, is great in sewage, but we have not known how to remove it. It has truly almost as little weight in proportion to the sewage itself as a man has to a castle.

In working with the apparatus described, a constant loss of ammonia was observed, and sometimes this was found by the smell itself. The sewage was tossed about; the volatile part was carried up by the currents of air, and it had no opportunity of returning. Here it was thought was at last a method of obtaining a revenue from sewage ammonia. If we take a grain of ammonia only out of a gallon of sewage, we have from a million gallons a million grains, equal to 142·81 lbs.—let us say 140 lbs.; let us for a large city like Glasgow multiply this by 50, and we have 7,000 lbs. of ammonia daily = 1,140 tons per annum, which at 60*l.* a ton, its present market price, is 68,400*l.* per annum.

Can we obtain a grain out of every gallon? In the laboratory with a small apparatus this has not always been done unless

lime has been used in sewage containing six grains of ammonia. In an experiment made in Glasgow with one hour's aeration without lime, two grains per gallon were obtained from sewage containing about nine grains of free ammonia, I am told. This appeared as a very remarkable and cheering fact, opening up a new field of action for sewage operations.

The question now came to be, How is this to be proved? We know that the world will not spend its money unless it can receive the hope of a good reward.

There is, however, a second question :—When the ammonia is removed from the liquid, how is it to be retained; that is, removed from the air which carries it up, and held in a concentrated form? The present ideas on that point have not been subjected to proof, but it is contemplated using either an acid or a solution of a salt, such as chloride of calcium; from which the ammonia, which has always carbonic acid along with it, would throw down carbonate of lime in fine division, and leave chloride of ammonium in solution.

It was found, however, that the idea had come into the mind of another, ten years before, and had been thrown away. A provisional specification of a patent had been made out in 1870: was it right to throw it aside, and must I do the same? The first projector seems to have acted from theory, and his plan was so imperfect that success, we can easily see, was impossible. A liquid must be very rich in ammonia before such a process would allow any important quantity to be taken from it, as there is simply a bubbling of air through the liquid. Another patent was taken out by Messrs. Hills and Biggs in 1872, one by Messrs. Welch and Scott in 1876, and one by W. L. Wise in 1878. I have tried only Dr. Storer's, and it is not for me here to give opinions of the comparative merits.

Ammonia removed by Exhaustion.

In aerating water by the method just spoken of, there is a removal of the gases contained in the water, and a substitution of air. This displacement is not effected without using a large amount of air, as one part of fresh air removes a small part only of the gases contained in the water. We cannot expect to do the same work with a small amount of air, unless we first remove the gases contained in the water. This may be done to a large extent by pumping them out; and it is remarkable how much is done, at least on a small scale, in a minute or two by this method. I cannot say that a result has been obtained equal to that by a current of air; and we must remember that the current acts oxidizingly as well as by displacement; but a great deal is effected by the exhaustion methods. The gases come off in a condition strongly impregnated with organic matter, and very disagreeable to the senses. They may in this case be sent through a disinfecting process; say, by passing a fire, if necessary, and if the ammonia cannot be got out. It was expected

that by taking them out in a concentrated state they could be passed through acid, and the ammonia removed in a small absorbing space, thereby getting over the difficulties which may be expected when we try to absorb the ammonia from a large amount of air. This, however, was not found in practice to take place to a sufficient extent; very little ammonia was removed by pumping. At the same time it is very probable that the failure was not inherent to the process, but caused by the limited and imperfect scale of laboratory operations. In some cases it is probable that ammonia would come off in this way; that is, when the sewage was stronger than usual.

If this method of pumping out the gases were adopted it would only be as a preliminary to aeration, which might be effected either by allowing the air to enter, or by assisting it.

How far this plan will be found useful in extracting ammonia from various decomposing bodies, other than sewage and solutions, is still to be found out, but it certainly seems to recommend itself in many cases where putrefaction causes offence, because the putrid gases are drawn out at once and may be treated by fire or otherwise rapidly. It is a new mode of disinfection.

Some enquiry is necessary to enable us to find if the plan of previous pumping out of the gases, and then aerating, is to be recommended in any case in preference to the mode of passing air through the sewage at first. My belief is that such cases may exist when ammonia is to be extracted, but they are more likely to be found where purification and oxidation are required, without looking to the ammonia. This pumping simply draws out the gases which are not very soluble in water, and makes room for others to enter. Those which enter are expected to be oxidizing agents; and first we must look to the action of common air. The sewage could be rapidly deprived of its gases, and then simply allowed to flow away. When it had flowed even a very short time the air would enter, and during this period more would come out. Still it cannot be denied that if the sewage smells badly, the removal of all the air that can be pumped out does not quite remove the smell. It does, however, diminish the quantity of gases and of vapour capable of causing a smell. If, however, the oxygen were caused to enter in a condition more concentrated than it is in the atmosphere, the oxidation would go on more rapidly. It has been a matter of thought to supply the concentrated oxygen to the sewage. We know what wonderful effects are caused by permangates and by peroxide of hydrogen; and I have shown also what high oxides, such as nitrates, effect. A careful study is not required to show that pure oxygen gas, at the present price of materials, is too expensive if we are to saturate the solution, or to give it two per cent. only. At the same time I have not ascertained how much would be necessary. Unless the action were very rapid, the amount would be rapidly diminished by diffusion, and the most active agents for supplying solid oxygen are too expensive.

Viewing the matter in this way, I have called to mind my experiments made long ago in the absorption of gases by charcoal. It was at one time apparently certain to me that oxygen could be filtered out of the air by charcoal; and, indeed, I have found large proportions of oxygen taken out by charcoal. Indeed, we may say that the amount removed from the air is, as a rule, 30 to 40 per cent. I have not, however, been always successful in obtaining it back by pumping it out of the charcoal; occasionally it has come out very well, but it has sadly disappointed me. The plans, however, are not all exhausted. The amount of gas regained from the charcoal usually has less oxygen than the air.

Finding that charcoal was not manageable I have had recourse to water. Pure water absorbs air, not exactly as such, but in the proportion of one-third and a little over of oxygen, the rest being nitrogen—leaving out traces. In other words, we can pump out of water a mixture containing about 13 per cent. more oxygen than common air contains. Such a great increase of per-centage of oxygen has a remarkable influence in most cases, and I suppose will have in oxidizing the substances in sewage. There is a disadvantage, namely, in the small total volume of air that can be obtained from water. In some cases this is of little consequence, because the water is abundant, and one would suppose a stream to be an endless source. In other places, it may be said, where should we obtain water? Water may be used as a filter; when it has been exhausted of air it begins again to drink it in; and the same may be repeated for ever. The question, however, remains, How rapidly can this be done? For example, what surface and depth of water are necessary to supply continuously a cubic foot of air having 13 per cent. of oxygen added to its present amount.

If this mode of obtaining oxygen were manageable, the water would not require to be pumped high; but it could be put into a closed vessel, first pumped for a short time and then allowed to pass off for more air. This water would require to be kept pure.

These are ideas regarding the supply of oxygen:—Methods of hastening the action of the air. Another method consists of using pressure to save time. The water, after being exposed to a vacuum, might be exposed to pressure with common air, or with the richer air from water, and pressure might be applied so as to finish the process very rapidly.

These methods of increasing the purifying action going on in water, are based on the first facts; namely, that a large and important effect is produced in one hour by passing air alone; next, that a more rapid effect is produced by pumping out the gases before passing air. The next effects, namely, of stronger mixtures of oxygen, may be considered certain, although not tried. The mode of obtaining oxygen is certain also, as shown by Mallet. The analysis of the air at successive stages is very

interesting (*see* 2nd Supplement, Watts's Dict., "Oxygen"), but the practicability of the process on a large scale has not been put to the test to my knowledge.

I send out these writings, being chiefly the description of work done, but partly of course looking forward to work that may be better done after the information here has been considered.

No. X.

Aeration of Water Supplies.—Drinking Water.

This is not quite a new subject to speak of, but it has not been well worked out. These latest ideas as to the value of air compel us to turn to it again. We have now many towns supplied with surface water without filtration. The result of this must be that there is some deposit in the reservoirs if the solid matter is not carried away. Perhaps I ought first to have said that there is solid matter in all cases nearly, although there may not be much. Indeed it is not easy for us to suppose that the washings of fields can be free from floating bodies. When the water sinks deep into the ground we have magnificent filtration and clear brooks. The experience described by Dr. Greenwood must not be forgotten, and we do not know the limits of the impurities from manured land. As a rule, however, it seems to be true that the organisms washed from fields, and coming into our streams, rivers, and reservoirs, are not hurtful. And why not? When we have the great dilution and the great aeration together we may draw the conclusion that the researches of Pasteur empower us, even when no opportunity is given for that destruction by putrefaction which has received favour in this Report. Still we have this fact before us, that in great floods there is little time for change, and the increase of material washed off the soil is equal to a diminished opportunity of oxidation. In such cases it does seem right that water should have some time to undergo its changes, or that it should be filtered, or both. The reason for filtration is twofold: we remove solids by it; and in removing visible although minute floating matter, we remove also much which is insensibly small. But this is not all: the act of filtration in a good filter is really an act of oxidation,—in sand, for example, and other porous bodies. Of this I have spoken elsewhere. When this is not sufficiently done, would it not be well to use mechanical aeration for drinking water? It is certain that many of our water supplies do not contain as much oxygen as the best water. Manchester, for example, has a fair supply of water, but it varies considerably, and the oxygen passes down to 27 in the 100 of air dissolved in it. How far this could be remedied by the use of more oxygen, it is not possible to say without trial, and it is a trial which ought to be made. This is rather an addition to the duties of waterworks proprietors, but it is one which comes with the changes of our habits. Our reservoirs are filled by streams in flood, and we do not wait until these rough

waters pass away leaving the calmer streams to be taken, such as are filled by the water filtering through the soil, and thereby purified, as they often are, to brilliancy.

In speaking of this it is natural to consider the use of lime now proposed in so many cases of purification. In Clark's process, for example, lime is used, and carbonic acid is removed. It has been asked if it would not be an improvement to add carbonic acid. I believe it would, and probably air also. In the first proposals for purifying water by Thomas Henry, F.R.S., Manchester, about a century ago, lime was used, and after precipitation carbonic acid was employed to neutralize any excess. Any excess of carbonic acid over the lime would be an improvement. Free lime in water is a great disadvantage. Indeed we must look carefully to our streams whenever lime is used for precipitation. It is a favourite poison for fish, and I have seen a clear solution from a precipitating tank become suddenly whitish on entering a river of clear water. The process was intended for purifying the river, but it was in reality adding a new poison. It was in small amount, certainly; but who knows the amount used at times? There must be a careful measure of lime used in all cases where a river may be affected.

This use of carbonic acid might take place along with air, and if the water were to be used rapidly, it would add sapidity, which is not obtained at once by natural aeration, and is best obtained by deep filtration or by carbonic acid.

We may now consider generally the effect to which the newest information regarding germs of minute life seems to point. Water, when standing long with germs of life, has, or may have, according to the weather, increase of growth. Abundance of air will be preventive of or destructive to many of the lower forms, certainly those that cause putrefaction. Stagnation allows the oxygen to be consumed. Filtration and aeration ought to take place just before the water is to be used, according to these views.

Note on Depositing or Filtering.

The use of filtration is great, and nature provides us by its means the best of water, which comes through soils holding many unlovely things, and still without carrying them forward. It is an important matter to imitate this, and we try with some success, but we cannot imitate the self-purification in nature as fully as we wish; we cannot remove the carbon so rapidly and make it from a constituent of a filthy compound to one of a pure gas. The consequence is that our filters become covered with much impurity, and through this all our water supplies go, that is, there is an accumulation which is not an imitation of nature as we find it on the soil, but a simple product of art. I do not ignore the fact that various modes have been devised of removing this, and I have much good feeling towards the oxidizing filters used, especially those with compounds of iron or iron itself, and I will not say that in some cases they are not by far the best to

be chosen; but it has seemed to me that it would be a fine thing if we could avoid completely the passage of water through an impure deposit, and if we could remove that as rapidly as it is formed.

Note on Mechanical Filters.

There are several such filters, and a remarkable one is devised by Mr. Bowing, in which the liquid to be filtered is pressed against canvas or cloth, which lies on a perfectly plain surface of metal. The water works its way between the metal and the cloth. The fact is curious, and the result is remarkable. How far this would do for finer water I do not know; it would probably be insufficient; but when applied to less pure liquids the result has been shown to be excellent. The advantage of the mechanical filter is that the deposit is removed rapidly, and is not allowed to remain and putrefy; and if it could be so applied for drinking water as to produce an unobjectionable result, we should rejoice.

I doubt if Mr. Bowing's filter, as made by Manlove and Alliott of Nottingham, has been tried otherwise than for sewage; but even then it seems as if it were too much to expect a good result on account of the enormous bulk of sewage to be passed. If, however, a deposit were allowed first, and mechanical filtration applied to it afterwards, we might obtain something of more value. I have nothing to say of new modes of filtration, but am looking to experiments on a large scale. I have not given sufficient attention to the spongy iron filter of Mr. Bischof's, but having got remarkable results from iron filings in 1848, I am much in favour of iron, and must give it more attention.

Precipitation in Drinking Water.

The very great attention given to precipitation of sewage has led us from its application to drinking water, and it is remarkable that we have so much neglected the possibility of improvement in this direction. We know the old methods of adding alum to muddy water and finding it rapidly cleared,—a method used in India and China, and probably elsewhere. We send many tons of alum to Asia for this purpose, as it is supposed. But then these Easterns are so careless that the water which they call not good for drinking is to us horrible, and that which they consider just drinkable is bad to our sight and smell. The wonderful clearness obtained by throwing down flocculent precipitates has been often remarked. It has occurred, however, to Mr. Peter Spence, of Manchester, to use an aluminous salt not merely for sewage and very impure waters, but also for town supplies, and the results obtained in Manchester water are remarkable. The substance he uses is called by him alumino-ferric cake, but the name can be readily altered. The salt is a sulphate of alumina, with only 0·7 per

cent. of oxide of iron in it. It is made from bauxite, a mineral containing chiefly soluble alumina.

The Manchester water is considered a very fair one; it is a little yellow, being coloured by peaty matter. But when this sulphate of alumina is added, and it is allowed to settle for two days, it obtains a brilliancy equal to all we can desire. I made some experiments, and obtained the following results. The estimation of the purity of tint made by my new method is as follows. (*See* for explanation, No. XI., p. .)

The highest numbers show the greatest transparency; but it must be remembered that it is only proportionate, that is, the same water does not give the same numbers on every trial, because the amount of light differs.

People may be afraid that alum will remain in solution, but there is rarely a water to be found so free of lime as not to decompose the small amount of sulphate of alumina used in these experiments. This point must of course be remembered, and the water kept alkaline.

TRANSPARENCY of the specimens, WEAK LIGHT, but STRONG SOLUTION to COMPENSATE, 50 c. c. contained 0·3 grm. SO_3 + 0·5 grm. KI.

—	Pure distilled Water.	Manchester Water purified by Alumino-Ferric Cake.	Manchester Water purified by Ferric Chloride.	Manchester Water after filtration through Blotting Paper.	Manchester Water.
1881.	c. c. $Na_2S_2O_3$ sol.	c. c. $Na_2S_2O_3$ sol.	c. c. $Na_2S_2O_3$ sol.	c. c. $Na_2S_2O_3$ sol.	c. c. $Na_2S_2O_3$ sol.
November 9th - -	25·0	25·0	21·0	17·4	13·6
„ 10th - - -	16·0	16·7	12·1	7·9	7·0
„ 14th - -	4·2	3·9	2·9	—	1·1
„ 15th - -	26·9 26·9	25·0	23·0	—	19·1 19·0
„ 16th - - -	30·5	29·0	26·0	—	22·0
„ 17th - - -	50·0	48·5	46·0	—	41·0
„ 18th - -	23·5	21·0	19·5	—	13·0

Could this result be obtained in great reservoirs? I can only say that it is so remarkable that it ought to be tried. It is certainly far beyond any method of filtering used at any water-works seen by me; it can only be compared to deep soil filtration. I must mention that I have not seen either the recent iron filters or the carbide of iron ones at use on a large scale, and cannot allude to them.

The alumina which falls takes down organic colouring matter, but the alumina may be dissolved out of the precipitate. How far it can be dissolved again is a point into which I have not entered. Mr. Spence says that for sewage this may be done repeatedly; in treating drinking water it may not act so well a second time, but the expense is certainly small. The amount I used for Manchester water was ·7 grains per gallon, or about a ton for 20,000,000 gallons, which ton would cost 50*s*.

The results of analysis are as follows, but it is enough to judge by the effect in brilliancy already mentioned:—

EFFECT of PRECIPITANTS on MANCHESTER WATER.
Analyses in Parts per 100,000.

—	Total Solid Matter.	Free Ammonia.	Albumenoid Ammonia.	Alkalinity as SO_3.
Manchester water - - - -	6·75	0·0022	0·0076	1·37
Do. with 1 part alumino-ferric cake per 100,000.	7·00	0·0028	0·0056	1·03
Do. with 1 part ferric chloride	7·16	0·003	0·0060	1·00

If this turns out as well as it promises it will be necessary to give up the method of using surface or flood water. Hitherto it has been allowed to settle only, but we can neither remove the colour nor the germs of life by any such process, and by precipitation we remove at least the visible part of the organic matter, and some of the very material on which organisms live. That none should be left, considering the very vital conditions of the world, it is not for us to expect even if it is to be hoped for.

Examination of this process continues. I look on it as chiefly valuable for throwing down fine floating matter, taking, however, some organic matter out of solution.

No. XI.

Mode of Estimating the Transparency of Water.

In the 16th Report under the Alkali Act, also in the proceedings of the Royal Society, Vol. XXX., I gave an account of a mode of measuring the amount of light over any given period of time. Finding that the idea had previously occurred to Dr. Leeds of the United States, I gave him of course the credit. However my intention was to pursue it for the purposes of my office, and to endeavour to measure the influence which fogs natural and artificial or smoke have on the amount of light transmitted through the atmosphere immediately above us. I also said that I intended to apply the knowledge to an estimation of the transparency of water. I have in my 16th Report under the Alkali Acts given a table of the total comparative light during six hours of the day for above a year, and in this report under the Rivers Pollution Prevention Act I now describe the same method as applied to water.

A few of the results are given, and I may say that they are most satisfactory. The order of the figures is certainly the same as I made out for myself by using the tube when the waters were brought to me without description; but I had a difficulty in judging. Time was required, a certain amount of anxious consideration was needful, and in one case I gave a decision, which, on reconsideration, I reversed. I may add that I am not behind in this mode of judging; two pairs of young eyes belonging to chemists were less correct and constant in their judgment, at least on this occasion. I say this to show the accuracy of the experiment, and to prove that we save time by it and uncertainty. However, this is not all. We obtain exact numbers, such as the eye cannot pretend to determine.

I always use of course as a standard distilled water, and it is necessary to have it in the experiment, as the numbers are not definite in a continuous sense on account of the constant change of light. They are comparable with pure water; but the same numbers do not occur on every experiment, as the light differs. The exact law of change requires study, but the order is certain.

Every new idea has its own mode of development, and I cannot tell how this may grow, considering all the various changes of colour in impure streams in this country; but for natural streams there is less difference of shade. I have here used it to define the brightening effect of precipitation as an example unless otherwise mentioned.

TRANSPARENCY.—TABLE I.

Transparency of Water with different Proportions of Chloride of Iron in Solution.

50 c. c. Solution containing 0·060 grm. SO_3 + ·5 gramme Potassium Iodide.

—	Pure Water.	Pure Water + 2½c.c. Fe_2Cl_6 per Litre.	Pure Water + 5 c. c. Fe_2Cl_6 per Litre.	Pure Water + 10c.c. Fe_2Cl_6 per Litre.	Pure Water + 20c.c. Fe_2Cl_6 per Litre.	Pure Water + 50c.c. Fe_2Cl_6 per Litre.	Pure Water + 60c.c. Fe_2Cl_6 per Litre.	Pure Water + 70c.c. Fe_2Cl_6 per Litre.	Pure Water + 80c.c. Fe_2Cl_6 per Litre.	Pure Water + 100c.c. Fe_2Cl_6 per Litre.
	c. c. $Na_2S_2O_3$ sol.	c. c. $Na_2S_2O_3$ sol.	c. c. $Na_2S_2O_3$.	c. c. $Na_2S_2O_3$.	c. c. $Na_2S_2O_3$.	c. c. $Na_2S_2O_3$.	c. c. $Na_2S_2O_3$.	c. c. $Na_2S_2O_3$.	c. c. $Na_2S_2O_3$.	c. c. $Na_2S_2O_3$.
July 5th, 1881. 8.45 a.m. to 6.15 p.m. - -	5·7	4·9	4·4	3·4	3·0	2·5	1·5	1·4	1·0	0·8
July 8th, 1881. 8.45 a.m. to 6.15 p.m. - -	3·0	2·0	2·0	1·0	0·7	0·3	0·0	0·0	0·0	0·0
July 9th, 1881. 8.40 a.m. to 2 p.m. - - -	4·0	3·5	3·0	2·0	1·0	0·5	0·0	0·0	0·0	0·0
July 11th, 1881. 8.35 a.m. to 6.30 p.m. - -	3·4	3·0	2·6	1·8	1·0	1·0	1·0	0·8	0·5	0·4

1 c. c. Standard Ferric Chloride = 10·15 mgms. Fe_2Cl_6 + 6·75 mgms. HCl (free).

TRANSPARENCY.—TABLE II.

TRANSPARENCY of WATERS with CHLORIDE of IRON in SOLUTION. DUPLICATE EXPERIMENTS showing CONSTANCY.

50 c. c. Solution containing 0·060 grm. SO_3 + ·5 gramme KI in 50 c. c. Flasks.

—	Manchester Water.	Manchester Water + 5 c. c. Standard Fe_2Cl_6 per Litre.	Manchester Water + 10 c. c. Fe_2Cl_6 per Litre.	Manchester Water + 20 c. c. Fe_2Cl_6 per Litre.
	c. c. $Na_2S_2O_3$ sol.	c. c. $Na_2S_2O_3$ sol.	c. c. $Na_2S_2O_3$ sol.	c. c. $Na_2S_2O_3$ sol.
York Place—				
June 28th, 1881 - - -	59·5 57·0	57·75 55·75	52·50 53·50	47·25 49·00
June 29th, 1881 - - -	8·85 8·85	8·5 8·5	7·7 7·7	7·0 7·1
June 30th, 1881 - - -	6·8 6·8	6·5 6·5	5·9 5·9	5·3 5·3
July 1st, 1881 - - -	12·1 12·0	11·4 11·5	10·9 10·9	10·55 10·6
July 2nd, 1881 - - -	8·55 8·5	8·3 8·2	7·9 7·75	6·5 6·5

TRANSPARENCY.—TABLE III.

TRANSPARENCY of MANCHESTER WATER and PEATY WATER.

50 c. c. Solution containing 0·060 grm. SO_3 + ·5 gramme Potassium Iodide.

—	Distilled Water.	Manchester Water.	Peaty Water.
	c. c. $Na_2S_2O_3$ sol.	c. c. $Na_2S_2O_3$ sol.	c. c. $Na_2S_2O_3$ sol.
1880, May 26th. After 21 hours	12·0	7·0	4·5
May 27th.	3·2	3·0	1·6
May 28th. After 3 hours	4·2	1·2	0·6
May 29th. After 16 hours	2·0	1·0	0·0
May 29th. After 44 hours	50·0	38·5	27·2
May 30th. After 3 hours*	47·0	28·0	18·0
May 31st. After 24 hours	14·5	9·6	4·6
June 1st. After $1\frac{1}{2}$ hours	10·7	6·5	4·2
June 1st. After 5 hours	7·5	5·6	2·6
June 2nd. After $16\frac{1}{2}$ hours	7·1	5·5	2·4
June 2nd. After 7 hours	6·9	3·7	1·6
Average	15·0	9·96	6·1

* This contained 0·300 grm. SO_3.

TRANSPARENCY.—TABLE IV.

MANCHESTER WATER and PEATY WATER. LITTLE LIGHT and MODERATE LIGHT.

Solution 50 c. c. containing 0·300 grm. SO_3 + ·5 grm. Potassium Iodide.

	Manchester Water.	Manchester Water containing 1 °/o Peaty Water.	Manchester Water containing 2½ °/o Peaty Water.	Manchester Water containing 5 °/o Peaty Water.
	c. c. $Na_2S_2O_3$ sol.	c. c. $Na_2S_2O_3$ sol.	c. c. $Na_2S_2O_3$ sol.	c. c. $Na_2S_2O_3$ sol.
1880, June 9th. After 2 hours, 11 a.m. to 1 p.m. - - -	7·1	6·4	4·2	1·3
June 9th. After 2½ hours, 1 p.m. to 3.30 p.m. - -	5·9	6·0	3·1	1·1
June 10th. After 3 hours, 9.45 a.m. to 12.45 p.m. - -	6·46	6·0	4·4	1·8
June 11th. After 3 hours, 12 noon to 3 p.m. - -	6·7	4·5	4·2	2·0
June 12th. After ½ hour, 10 a.m. to 10.30 a.m. - -	8·6	8·6	5·6	1·6
June 12th. After 17 hours - - - - -	25·8	25·8	20·0	17·3
June 10th. After 21¼ hours, 1.45 p.m. to 11 a.m. - -	17·3	16·5	15·0	12·0
Average - - - -	11·2	10·5	8·07	5·3

One per cent. is very decided on the average numbers, but has variations. After one the result is decisive.

TRANSPARENCY.—TABLE V.

MANCHESTER WATER with SEWAGE and PEATY WATER. A FAIR AMOUNT of LIGHT.

Same Solutions in each.	Manchester Water.	Manchester Aq. containing 3·52 % Sewage.	Manchester Aq. containing 7·04 % Sewage.
	c. c. $Na_2S_2O_3$ sol.	c. c. $Na_2S_2O_3$ sol.	c. c. $Na_2S_2O_3$ sol.
1880, June 5th. After 18 hours	10·4	7·0	3·2
June 6th. After 45 hours	25·5	18·3	10·7
	Manchester Water.	Manchester Water containing 2·8 % Peaty Water.	Manchester Water containing 5·6 % Peaty Water.
1880, June 2nd. After 23 hours	5·5	3·2	2·0
June 4th. After 24 hours	13·0	3·0	2·0
June 5th. After 24 hours	9·4	4·0	2·7
June 6th. After 45 hours	26·4	13·0	10·0

TRANSPARENCY.—TABLE VI.

DISTILLED WATER. MANCHESTER WATER and SEWAGE in WEAK LIGHT.

Solutions containing in 50 c. c. 0·06 gramme SO_3 + ·5 gramme KI.

——	Pure Distilled Water.	Manchester Water.	Pure Water + $2\frac{1}{2}$ % Sewage Water.	Pure Water + 5 % Sewage Water.	Pure Water + 50 % Sewage Water.
1880, June 22nd. 10 a.m. to 4.30 p.m.	2·5	2·0	1·7	0·7	0·3
June 23rd. 10 a.m. to 4 p.m.	1·45	1·30	1·1	0·9	0·4
June 24th. 10 a.m. to 4 p.m.	5·0	4·1	3·8	3·6	0·3

PART II.

EFFLUENTS FROM PRINTWORKS, DYEWORKS, &c.

Precipitation.—General Rules.

If the effluents from dyeworks or printworks are alkaline, containing organic substances coloured or otherwise, an acid generally throws down a decided amount of solid matter. If the effluent contains soap, the fatty matters are separated, and fall or rise to the surface. These fatty matters may contain a large amount of colouring matter which may or may not be of value.

If acid is expensive at the place of precipitation a similar result can be obtained by chloride of calcium or any cheap metallic or earthy salt. Chloride of calcium is the simplest, and has a great influence. Its effect is not limited to the soap, but is observed in the effluents from paper works, and other cases where the liquids are alkaline.

Salts of calcium are, therefore, very valuable; and as they are found at bleachworks, printworks, and paperworks, and wherever bleaching is done, they have a great influence on the discharges. This influence is not always seen at once; it requires some time, and it would appear as if settling tanks were absolutely necessary. It would be very good if we could hasten this precipitation. To some extent this is done by adding metallic or aluminous salts, but it is done also by stirring or shaking, as we often find in a laboratory, and previous to allowing the solution to rest. Thinking of this, one would have supposed that very violent action would have assisted still more the fall; but this was not the case; we found that by agitating the effluents after mixture with the precipitant, these could be reduced to a state of division so fine as to delay their fall.

The advantages of chloride of calcium are that it is frequently a waste product, and a great deal could be obtained if it were wanted.

Lime will certainly throw down the fatty matter of soap, and it will also take a great deal of solid matter out of the effluents of paper and other works, but it will not neutralize in such cases; on the contrary, it causticises these liquids. Chloride of calcium also can be thrown in considerable quantities into a river without injury, whereas this is not the case with lime.

The first thing to be done with the effluents from works generally is to allow them all to mix together, when large precipitates occur, and frequently complete neutralization, arising from this, namely, that the processes have required equivalent amounts of acid and alkali, although they escape separately. Cases exist, however, in which such a mixture would be of no advantage; and in other cases, as in alkali works, the mixture of the acid and sulphide liquors produces intolerable results.

The works, however, specially under consideration give out liquids which by this treatment cause considerable and sometimes large precipitates. The addition of chloride of calcium causes a second precipitate frequently, and it may be that this will be in some cases a sufficient treatment.

When better results are required, it is apparently essential to use salts of iron or aluminum; and few waters from these works under consideration will not become clear after this treatment; most, if not all, can be made also nearly colourless.

It would be quite wearisome to detail all the experiments made to come to these conclusions, but various results will be here given, and they may be compared also with those from sewage treatment.

Effluents from Paper Works.—May 1878.

Discharge Water from Settling Ponds, Carron Grove Works.—19th April 1878.

(1.) After filtration,—
10 lbs. Alum, 2·5 lbs. Lime } per 1,000 galls.
Volatile = 4·9 gr. per gall.
Mineral = 65·94 „
Total = 70·84 „

The filtrate was slightly acid; colour = 0·1 c. c. NH_4Cl with Nessler. No permanent froth on shaking.

(2.) After filtration,—
8 lbs. Alum, 2·5 lbs. Lime } per 1,000 galls.
Volatile = 5·67 gr. per gall.
Mineral = 57·33 „
Total = 63·00 „

The filtrate was faintly alkaline; colour = 0·4 c. c. NH_4Cl with Nessler. No permanent froth on shaking.

(3.) After filtration,—
4 lbs. Alum, 2·5 lbs. Lime } per 1,000 galls.

The filtrate decidedly coloured. Permanent froth on shaking.

Sample received 29th April 1878.

(4.) After filtration,—
10 lbs. Alum, 2·5 lbs. Lime } per 1,000 galls.
Volatile = 0·28 gr. per gall.
Mineral = 76·16 „
Total = 76·44 „

Similar to No. 1.

(5.) After filtration,—
8 lbs. Alum, 2·5 lbs. Lime } per 1,000 galls.
Volatile = 11·48 gr. per gall.
Mineral = 77·55 „
Total = 89·04 „

Similar to No. 2 as to froth. Filtrate slightly coloured.

(6.) After filtration,—
6 lbs. Alum, 2·5 lbs. Lime } per 1,000 galls.

Filtrate decidedly coloured. Froth lingered slightly.

Sample received 19th April 1878.

(7.) After filtration,— $2 \cdot 5$ lbs. $Fe_2(SO_4)_3$, persulphate of iron. Lime quant. suff.	The lime was added immediately after the iron sol. Filtrate slightly coloured.
(8.) After filtration,— $1 \cdot 25$ lbs. $Fe_2(SO_4)_3$ Lime quant. suff.	The lime was added five minutes after the iron sol. Filtrate was colourless.
(9.) After filtration,— $0 \cdot 7$ lb. $Fe_2(SO_4)_3$ excess powdered chalk.	The ppt. settled readily. Filtrate clear; did not froth.

Clarification of Logwood Waste Liquors.—March 1879.
Exit Liquor from Works.

(1.)	100 lbs. Alum Cake, 7·5 lbs. Lime	per 1,000 galls.	Colour almost gone.
(2.)	20 lbs. Alum Cake, 1·5 lb. Lime	per 1,000 galls.	97 °/₀ colour removed.
(3.)	10 lbs. Alum Cake, 0·76 lb. Lime	per 1,000 galls.	95 °/₀ colour removed.
(4.)	6 lbs. Alum Cake, 0·76 lb. Lime	per 1,000 galls.	90 °/₀ colour removed.
(5.)	4·74 lbs. Ferric Chloride, 6·00 lbs. Lime	per 1,000 galls.	99·8 °/₀ colour removed.
(6.)	2·16 lbs. Ferric Chloride, 4·56 lbs. Lime	per 1,000 galls.	98 °/₀ colour removed.
(7.)	0·66 lb. Ferric Chloride, 2·28 lbs. Lime	per 1,000 galls.	70 °/₀ colour removed.

NOTE.—There was a little free HCl along with the Fe_2Cl_6, ferric chloride or perchloride of iron.

(8.)	18·5 lbs. hydrated alumina	per 1,000 galls.	60 °/₀ colour removed.
(9.)	4·12 lbs. Fe_2Cl_6, 12·5 lbs. HCl, 5·0 lbs. Lime	per 1,000 galls.	Colour destroyed. The ppt. settles rapidly and perfectly.
(10.)	2·1 lbs. Fe_2Cl_6, 6·25 lbs. HCl, 2·5 lbs. Lime	per 1,000 galls.	Colour destroyed. The ppt. settles rapidly and perfectly.
(11.)	1·25 lbs. Fe_2Cl_6, 2 lbs. Lime, 3·75 HCl	per 1,000 galls.	Filtrate faintly coloured. Ppt. settled fairly, but left a turbidity in the liquid, which, however, was readily removed by filtration.
(12.)	0·85 lbs. Fe_2Cl_6, 2·5 lbs. HCl, 1·5 lbs. Lime		The ppt. behaved as in No. 11, but the filtrate was distinctly coloured.

(13.) 200 lbs. $CaCl_2$, chloride of calcium, per 1,000 galls. removed 60 °/₀ of the colour.

Clarification of Liquors from Woollen Mill.

Contents of last Tank before entering "Lade," Copperas, or protosulphate of iron, or ferrous sulphate.

(*a.*) 8 lbs. Ferrous Sulphate, 0·5 lbs. Lime } per 1,000 galls. — 66 % colour removed.

(*b.*) 8 lbs. Ferrous Sulphate per 1,000 galls. — 39·3 % colour removed.

(*c.*) 12 lbs. Ferrous Sulphate, 0·5 lb. Lime } per 1,000 galls. — 84·5 % colour removed.

(*d.*) 12 lbs. Ferrous Sulphate per 1,000 galls. — 78·7 % colour removed.

(*e.*) 2·6 lbs. Fl_2Cl_6, (?) Lime } per 1,000 galls. — 89·4 % colour removed.

(*f.*) 8 lbs. Alum, 0·5 lb. Lime } per 1,000 galls. — 71 % colour removed.

(*g.*) 8 lbs. Alum per 1,000 galls. — 72·5 % colour removed.

(*h.*) 6·5 lbs. Fe_2Cl_6, 5·6 lbs. Lime } per 1,000 galls. — 95·6 % colour removed.

(*i.*) No. (*h*) with 8 lbs. Copperas per 1,000 galls. 98·9 % colour removed.

The ferrous salt was added to destroy the chromate which was left by the ferric salt.

(*j.*) 3·7 lbs. Fe_2Cl_6, 8·0 lbs. Copperas, 2·75 lbs. Lime } per 1,000 galls. — 96·5 % colour removed.

(*k.*) 3·7 lbs. Fe_2Cl_6, 20 lbs. Copperas, 2·75 lbs. Lime } per 1,000 galls. — 97 % colour removed.

(*l.*) 7·4 lbs. Fe_2Cl_6, 4·0 lbs. Copperas, 5·5 lbs. Lime } per 1,000 galls. — 96·5 % colour removed.

(*m.*) 3·7 lbs. Fe_2Cl_6, 2·75 lbs. Lime } per 1,000 galls. — 92 % colour removed.

(*n.*) No. (*m*) with 8 lbs. $FeSO_4 . 7 H_2O$ per 1,000 galls. No further change. Comp. (*h*) and (*i*).

(*o.*) No. (*n*) with 1·4 lbs. Lime per 1,000 galls. 98·2 % original colour removed.

The liquid flowing from the ppt. obtained in expt. (*j*) gave—

Volatile matter	8·4 grs. per gall.
Mineral "	24·5 "
Total	32·9 "

Before clarification the liquid contained—

Volatile matter	81·9 grs. per gall.
Mineral "	119·0 "
Total	200·9 "

(*p.*) 5 lbs. $CaCl_2$, 1·5 lbs. Fe_2Cl_6, 11·0 lbs. SO_3 } per 1,000 galls. (neutral iron sol.) — Filters slowly. Filtrate coloured blue.

(*q.*) 5 lbs. $CaCl_2$, 1·5 lbs. Fe_2Cl_6 } per 1,000 galls. (neutral iron sol.) — Similar to (*p.*)

(r.)	5 lbs. $CaCl_2$ 1·5 lbs. Fe_2Cl_6 with 3·0 lbs. HCl (Acid solution of iron.)	per 1,000 galls.	Filters clear. Filtrate slightly yellow.
(s.)	5 lbs. $CaCl_2$ 1·5 lbs. Fe_2Cl_6 2·0 lbs. HCl	per 1,000 galls. (neutral iron sol.)	Filtrate blue and turbid.
(t.)	5 lbs. $CaCl_2$ 1·5 lbs. Fe_2Cl_6 3·0 lbs. HCl	per 1,000 galls. (neutral iron sol.)	Filtrate coloured; not very clear.
(u.)	5 lbs. $CaCl_2$ 3 lbs. HCl	per 1,000 galls.	
	To the filtrate from the foregoing— 2 lbs. Fe_2Cl_6 (neutral) per 1,000 galls. ? Lime (till faintly alkaline).		The filtrate from the iron was good.
(v.)	5 lbs. $CaCl_2$ 4 lbs. SO_3, sulphuric acid calculated as anhydride.	per 1,000 galls.	Filtrate slightly alkaline.
(w.)	5 lbs. $CaCl_2$ 20 lbs. SO_3	per 1,000 galls.	Filtrate slightly turbid.

Mixture of polluted liquids from Woollen Mills.

20 lbs. sulph. acid 4·12 lbs. Fe_2Cl_6 12 lbs. CaO	per 1,000 galls.	Filtrate colourless.
20 lbs. sulph. acid 0·82 lb. Fe_2Cl_6 5·0 lbs. CaO	per 1,000 galls.	Filtrate colourless.
lbs .O. V. 0·41 lb. Fe_2Cl_6 4·0 lbs. CaO	per 1,000 galls.	Filtrate slightly coloured.
5 lbs. $CaCl_2$ $8\frac{1}{4}$ lbs. Fe_2Cl_6 CaO	per 1,000 galls.	Colourless.
2·5 lbs. $CaCl_2$ 2·1 lbs. Fe_2Cl_6 6·6 lbs. HCl ? CaO	per 1,000 galls.	Colourless.

Clarification of Spent Log-wood Dye Liquors.

Very strong. Direct from Vat, and Undiluted.

Alumino Ferric Cake.				Ferric Chloride.			
Lbs. Chemicals per 1,000 galls.	Al_2O_3 per 1,000 galls.	Equivalent of Fe_2O_3.	°/₀ of Colour removed.	Lbs. Chemicals per 1,000 galls.	Fe_2O_3 per 1,000 galls.	Equivalent of Al_2O_3.	°/₀ of Colour removed.
	Lbs.	Lbs.			Lbs.	Lbs.	
17·5 lbs. cake - -	2·4	3·8	—	10 lbs. ferric chloride -	3·8	2·4	
4·6 lbs. lime - -	—	—	99	4 lbs. lime - - -	—	—	98·4
10 lbs. cake - -	1·4	2·17	—	5 lbs. ferric chloride -	1·9	1·225	—
2·3 lbs. lime - -	—	—	95·8	2·6 lbs. lime - -	—	—	84·0
5 lbs. cake - -	0·7	1·085	—	3 lbs. ferric chloride -	1·14	0·735	—
2 lbs. lime - -	—	—	88	1·6 lbs. lime - -	—	—	75·6
4 lbs. cake - -	0·56	0·868	—				
3·5 lbs. lime - -	—	—	82				
3 lbs. cake - -	0·42	0·651	—				
1·6 lbs. lime - -	—	—	71·6				

Miscellaneous Trials on Coloured Waters.

Spent Tan Liquids.—The acid liquid from a spent bark vat treated in Storer and Cranston's apparatus. Four hours' aeration did not alter its appearance, or render it more amenable to filtration.

By precipitation with a per-salt of iron and lime, a much better result was obtained in the liquid before aeration. The aerated specimen gave a much more coloured filtrate.

When the liquid was made alkaline with lime and then aerated, it darkened rapidly and considerably in colour. The colouring matter was somewhat soluble, and gave a strongly coloured filtrate.

A fair clarification may be obtained by adding lime to the unaerated liquid (which may require dilution), separating the insoluble, and aerating the clear liquid. A second ppt. is obtained, after the separation of which the liquid appears fairly pure.

Peaty Water.—A sample of strong peaty water was aerated in Storer's converter. After two hours' action 20 per cent. of the colour was destroyed; further aeration was of no benefit. Two grains lime per gallon were then added, when half an hour's action destroyed another 30 per cent. of the colour; *i.e.*, 50 per cent. of the original was destroyed. Further aeration was not of use.

Two grains of lime per gallon added to the same water without aeration intensified the colour considerably.

Dye-house Liquids.—A sample of liquid from Bradford chiefly contaminated with logwood was aerated. No apparent change took place after two hours' treatment; but the addition of 25 gr. CaO per gallon, and half an hour's further aeration, gave a better result than the simple addition of lime without aeration.

A sample of logwood liquor from Brinscall was aerated. After $1\frac{1}{2}$ hour there was a decided diminution in the colour of the filtered liquid compared with the original liquid likewise filtered. 13·2 gr. CaO per gallon were now added, which further lessened the colour of the filtrate; continued aeration (two hours) was of little use.

A sample of the above liquor from Messrs. Wood's was pptd. with 26·5 gr. CaO per gall., and the filtrate aerated. Two hours' aeration destroyed 20 per cent. of the colour, five hours' 24 per cent. of the colour.

Logwood was examined qualitatively with BaO_2, BaS, CaS, and H_2O_2.

BaO_2 gave the best result; then came BaS, soda waste, H_2O_2 and CaS. This arrangement is according to the immediate effect. The H_2O_2 continued to act slowly, and gave a better result after standing some time.

Logwood liquor treated in the converter with soda waste for two hours had a stronger colour than by simple lime precipitation (20 grm. waste to 15 litres liquor).

Logwood liquor which had been treated with lime and afterwards aerated was submitted to the action of ozonized air in the converter, but no further decrease of colour ensued.

A quantity of logwood liquor was enclosed in a glass tube along with oxygen under pressure of two atmospheres, but no apparent change took place after 10 days.

Iron and Tin Plate Works.

The solution coming from these works consists entirely of sulphate of iron with a little extra acid. The acid is in nearly all cases sulphuric. I have proposed some rules which for the present are very mildly stated.

"Some Rules applicable especially to Works in South Wales."

1. After the 31st day of December 1880, it is expected that at every tin and iron work the solutions of sulphate of iron or copperas, being the liquids remaining after the processes in which the acid solutions called "black pickle" and "white pickle" are used, shall be treated or removed in such a manner as shall prevent any of it flowing to any river or stream.

2. It is not proposed to insist at present that the water used for washing the plates which have been taken out of the acid or pickle shall be treated in such a way as to remove all the acid. It is, however, known that there are two methods by which it may be done; one by passing the plates singly through rollers, and thus removing the acid almost entirely. If the water should contain a little carbonate of lime in solution, it may be enough, and it is in a known case in the district more than enough to neutralise all the remaining acid. The second plan is to dip the plates in a cistern of water before exposing them to the great rush of wash water. This cistern removes nearly all the acid, and will last a long time. The solution will require to be boiled down along with the so-called pickles, or otherwise treated so as to be innocuous.

I wish to call attention to this point, namely, that at present I should not think it right to give a certificate under the Act unless one of these methods is adopted, or a better.

3. Dregs of the crystallising vessels containing sulphate of iron are not to be thrown on the ground in such places as render them liable to be washed into streams. The dregs ought to be thrown away only after the copperas is fully washed out.

4. All the work must be done in such a manner as to be easily inspected. It must be open and free to the surface in every possible case.

Encroachments on the Rivers.

I propose that in every case causing suspicion, fear, or complaint a retaining wall of about 3 ft. high from the surface be made adjoining the river, and marking the limit of deposit of refuse or "tipping." This wall to be not less than twelve inches in breadth, and to be kept in good order. The heaps or refuse not to extend to the edge of the top of the wall next the river, but to be limited to the inner edge of the wall. When this point is reached grass to be sown on the refuse. Grass will grow, although slowly, on almost every kind of heap, and if there is any difficulty a little dusting of earth is sufficient to raise it. A small amount is sufficient to show that no trifling with the rule takes place, but that "tipping" at the spot has ceased.

ALKALI WASTE HEAPS AND DRAINAGE.

On Aeration and Oxidation in Watery Solutions of Soluble Sulphides.

The waste heaps made near alkali works, or by the tank waste from alkali works, wherever laid down, have been a frequent source of complaints. They give out, according to their condition, sulphurous acid or sulphuretted hydrogen; and the drainage water from the ground covered by the waste containing much sulphide gives out the latter gas in great abundance, according to the condition of the air or the rain whilst the influence is felt as far as the stream flows. Sulphur in the meantime is deposited, as it is not a simple sulphide, but a double or a penta-sulphide, or a mixture of sulphides, which is contained in the yellow fluid. I may as well extract from the reports relating to the Alkali Acts 1877 and 1878, p. 12, the following general observations which will introduce the subject :—

"Many attempts have been made to recover the sulphur from the great heaps of lime salts so frequently seen about soda works. These heaps contain at first a large amount of sulphide of calcium. This sulphide of calcium is not very soluble, and it seems at first to be a mono-sulphide; gradually, however, it absorbs oxygen, and, being moist in the condition in which it is laid down, gives out sulphuretted hydrogen. First the carbonic acid of the air along with water decomposes the sulphide so that sulphuretted hydrogen passes off; next the oxygen of the air oxidizes the calcium, which sets free sulphur, which again in its nascent state becomes oxidized: these two processes forming hypo-sulphite of calcium (*i.e.* thio-sulphate). Another process, which may either be called a third or fourth, is the formation of sulphurous acid. This is formed, I suppose, by the heat igniting the sulphuretted hydrogen, but not entirely so. The heat decomposes the gas, and in the absence of air produces fine sulphur, which is seen deposited on the heaps and in

all the gas passages. This sulphur is ignited as the heat advances, and it burns according as the oxygen is supplied; the process may be so slow that the heap cools before the sulphur receives its supply of oxygen. The action of the air, if followed further, leads to an oxidation of the hypo-sulphite into sulphite, and afterwards slowly to sulphate, when the final stage is reached.

"The result to the atmosphere may be, first, the spread of sulphuretted hydrogen, second, the spread of free and sublimed sulphur, and third, the spread of sulphurous acid. If it is asked why these two gases, sulphuretted hydrogen and sulphurous acid, are put together as being in the atmosphere, seeing that they decompose each other, I then add that they do not decompose instantly when in a very dilute state in the air, and I might also add that it is not proved that they come from the exact same point of the decomposing or oxidizing substances.

"In any case these gases are offensive, but if in a concentrated form, or rather if a considerable quantity of each is put together, or if they meet in water, the result is that the sulphur of both is thrown down in a free state, and no smell of either gas of course can be perceived; both have ceased to exist. It has therefore been the object of several inventors to cause the sulphur to be partly oxidized into sulphurous or more conveniently into hyposulphurous acid, so as to form hyposulphite of lime, a salt whose acid is converted into sulphurous acid and sulphur when acted on by any strong acid. This result has been attained, especially by Mr. Mond, who oxidizes a certain portion of the sulphur in the waste by blowing air through it; and when the exact amount of hyposulphurous acid is formed capable of destroying the sulphide of hydrogen or calcium remaining, he dissolves in water all that will dissolve, and adds hydrochloric acid, which releases both the acids so as to let them act upon each other. The result is that the sulphur is thrown down free and useful instead of combined and noxious.

"Not many people have used this process; it was said to be troublesome, it required considerable capital to establish; still there was, and I suppose still is, a profit on the sulphur regained. This is fully established by Mr. Worsley, of Netham, near Bristol, who, however, showed that the profit was not great, and that most of the manufacturers preferred to use their capital in another direction. It was a question whether they ought not to be compelled to adopt some plan of purification. Where capital is abundant, it might not be a hardship; where money is scarce it was said to be decidedly so.

"Then it was said that the remaining waste or undissolved lime salts which still contained some sulphur combined in sulphide of calcium, decomposed more readily than when Mr. Mond's process was not used, and that they sent out (for a shorter time certainly) but still for a time, more of the offending gases. I do not think that this was a valid objection by any means; when the waste is well oxidized by this method, it certainly is more porous, but if well washed the oxidation does not produce offensive gases to an

extent that could be perceived twenty yards off. This was the result of examining the heap at Netham.

"Another objection was that the remaining lime compounds being loose did not form such a solid base for building on as the old waste. I do not see that this is correct; the old waste swelled out very much for many years, and was often a very dangerous heap, as, if high, it was apt to fall in great masses. The waste formed by Mond's process does not swell out so much as the ordinary, because the sulphur is removed, and less oxygen and water are required to form the sulphate of lime. Time has not allowed us to see any structures built on the new waste or that from Mond's process. The waste by the old plan must lose a very large amount of soluble matter by rain, as the hyposulphite is very soluble in water. The lightness of the waste is probably caused in the blowing apparatus in which it is puffed up; if so, it will return by pressure to the normal weight of a sulphate.

"It is in the drainage that the difference of the two is most seen. The old method gives waste which sends out sulphureous solutions for many years. The new method may be so employed as to send out drainage in which the senses cannot detect sulphur: this I saw effected at Netham. A similar result was observed where Emil Kopp's method is used at Dieuze.

"The ultimate results of the two will be that in the old waste there will be more sulphate, and by the new processes more carbonate. Besides this there will be more lime dissolved out by Mond's and by the new processes in the condition both of sulphide and hyposulphite. The sulphates are not so suited for a foundation as the carbonates, being more soluble in water; the first about one in 400.

"There is another plan of treating the waste to be seen at Dieuze in Alsace. It was developed chiefly by Dr. Emil Kopp. Sulphate or chloride or any soluble salt of iron is thrown on the waste in small quantities, less than five per cent. The quantity is not important, but if very small the action will take a longer time. The iron is converted at once into a sulphide, and if turned over and exposed to the air it becomes an oxide, and the sulphur is set free, and in this way it is converted and reconverted until a sufficient amount of sulphur is removed from the calcium. The oxidation of the iron is always accompanied by the oxidation of sulphur into a hyposulphite. The excess of lime in the mass dissolves the sulphur, the heating of the whole being sufficient for this purpose. The solutions of sulphide and hyposulphite are mixed so as to contain the necessary proportions.

"These processes demand acid in order to set free the sulphurous and hydrosulphuric acids, and hydrochloric acid is the most suitable, but it has been presumed too often in estimating the value of these processes that it has little or no marketable value. When bleaching powder is in demand, the acid is valuable, and in all places, so far as I know, where it is made on the continent it is of a decided value. To avoid using too much, Mr. McTear has invented a process in which sulphurous acid takes its place to a considerable extent."

Process of Dieuze.

"This process, I believe, was first proposed by Dr. Emil Hofmann, developed by E. Kopp, and advanced under the care of M. Marchal. A report on the process was written by Professor Rosenstiehl, of Mulhouse, and communicated to the British Association by Mr. I. Lothian Bell, M.P., but I do not find that anything above a short notice has appeared in English. I shall extract from the memoir by Professor Rosenstiehl whatever may seem to be of interest to English alkali makers at the present time.

PROCESS, as used at DIEUZE, for recovering SULPHUR from the WASTE HEAPS, REPORT by PROFESSOR ROSENSTIEHL, of Mulhouse, 1867 (and still in use in 1878).

"The solid residue left on lixiviating crude soda is called "marcs de soude" or "charrée." The elements which compose this substance are sulphur, carbonate of lime, caustic lime, silicates, and water, in proportions which greatly depend on the purity and division of the materials employed in the manufacture of soda. Generally the fresh "waste" contains 12 to 16 per cent. of sulphur according to the quantity of water remaining with it.

"The residual liquors from the manufacture of chlorine contain the chlorides of manganese, iron, and barium, free chlorine, free hydrochloric acid and water, in proportions which vary with the nature of the manganese employed.

"The following is the composition of the liquors at Dieuze according to an analysis made by M. Hofmann:—

Manganous chloride	22·
Ferric "	5·5
Baric "	1·06
Free chlorine	0·09
Hydrochloric acid	6·80
Water	64·55
	100·00

"These are the residues in question which it is proposed to transform into inoffensive residues or useful products, but in either case without the consumption of fuel.

"The different steps in the process may be summed up as follows:—

1. Transformation of the waste into soluble sulphur compounds (yellow liquors).
2. Precipitation of the sulphur by the acid in the chlorine residues; neutralization of these.
3. Elimination of iron by fractional precipitations.
4. Precipitation of manganous sulphide.
5. Combustion of this sulphide.
6. Utilization of the ash of the sulphide.

1.—*Transformation of the Waste into Soluble Sulphur Compounds. (Production of Yellow Liquors.)*

When acid is poured into a mixture of two molecules of a polysulphide and one molecule of a hyposulphite, all the sulphur contained in these bodies is precipitated, and neither sulphuretted hydrogen nor sulphurous acid is evolved. One molecule of hydrochloric acid thus producing at least one atom of sulphur (S=32) and at most two atoms, according as the solution contains a bisulphide or a pentasulphide.

We may thus with a small expense of acid produce a relatively large quantity of sulphur and avoid all evolution of gas. On this reaction the regeneration of sulphur is based. It is necessary to convert the sulphide of calcium in the waste into a polysulphide and hyposulphite.

When the waste is exposed to the air the simultaneous action of carbonic acid, oxygen and water, induces the formation of soluble compounds of which I have spoken.

But the reaction is slow; it requires not less than 8 to 10 months for completion, that is to say, to furnish a residue no longer containing sulphides. The necessary consequence of this tardy action is, large surfaces of ground for the decomposition of the daily yield of waste.

This process, condemned by practical men, has been so successfully modified at Dieuze that it allows the extraction of 44 per cent. of the total quantity of sulphur contained in the waste, in the form of soluble compounds, and that in the space of 8 days.

This modification, which forms the novelty of the process, consists in the incorporation of a certain quantity of sulphides of iron and manganese with the waste. These sulphides are obtained by treating the neutralized chlorine residues with a little waste until almost all the iron is precipitated as sulphide; at this time the greater part of the manganese is still in solution; this liquid is run off, and the residue is mixed with the waste, which is allowed to remain exposed to the air for 6 or 8 days.

The air acts energetically on this mixture, and the sulphuretted compounds are formed rapidly. The formation of these polysulphides and hyposulphite requires the presence in the mass of free sulphur. Now, according to the observation of M. Hofmann, sulphide of manganese exposed to the air is transformed into oxide and free sulphur; the oxide of manganese may again be made into sulphide, and pass through the same changes; a part of the waste is thus found decomposed into caustic lime and free sulphur.

Analyses made by the chemist already cited prove in fact that the final residue contains a larger proportion of free lime than the waste itself.

In the theory described, I have intentionally ignored the presence of sulphide of iron. Its action is not yet *defined* by direct experiment, and from its proneness to oxidation might readily favour the formation of calcium sulphate, and thus have a less

useful effect than the sulphide of manganese. The liberated sulphur forms polysulphides with a portion of the sulphide of calcium, and hyposulphite with another portion, under the influence of the air.

For practical purposes it was very important to know how to produce separately one or other of these compounds. The advantage was thus obtained of mixing them in such proportions that an evolution of sulphuretted hydrogen or sulphurous acid should be completely avoided when acted upon by acid.

This important result was obtained by observing carefully the progress of the oxidation.

The waste containing the sulphides of iron and manganese is exposed to the air in heaps for eight days. The interior of the mass heats and would arrive at incandesence if care were not taken to turn over the heap during the interval. In this manner the temperature rarely exceeds 90° (C.) The lixiviation of this modified waste furnishes a saturated solution of a polysulphide of calcium; there is only a small quantity of hyposulphite produced; doubtless the high temperature destroys this latter compound, it being decomposed at 50° (C) into polysulphide and sulphate.

After this first lixivation the residue is again exposed to the air for two or three days, then it is washed a second time. In this case the temperature is less elevated, and considerable quantities of hyposulphite are formed. The residue from the second washing, exposed to the air, again heats, the sulphides of iron and manganese being oxidised, in this case no product is obtained by washing.

According to an analysis of M. Hofmann, this residue is composed of—

Sulphate of lime - - -	66·248
Carbonate „ - - -	1·320
Caustic lime - - -	20·982
Oxide of iron and alumina - -	7·
Oxide of manganese - -	1·500
Insoluble matter - - -	2·800
	99·85

This residue does not occupy more than two-thirds of the original volume of the waste; it does not now contain any substance which, by dissolving in the drainage water, could injure vegetation or manufactures.

I have often examined the drainage water from heaps of the residue, and have been able to prove the absence of soluble sulphides; this fact is important from a sanitary point of view.

It has been said that the result of the first washing is a solution of polysulphide of calcium in which acids produce an abundant precipitate of sulphur and an evolution of sulphuretted hydrogen.

The second washing gives a mixture of polysulphides and hyposulphite in such proportions that an acid produces a feeble disengagement of sulphurous acid, and at the same time an abundant precipitate of sulphur. These two solutions are employed separately; the first is used by preference for the neutralization of the chlorine liquors and the production of sulphur, and the second serves for the production of sulphide of manganese.

From their beautiful golden colour these liquors are called the yellow liquors, and to distinguish them from each other the first is called sulphuretted yellow liquor (eaux jaunes sulfurées), and the second oxidised yellow liquor (eaux jaunes oxidées).

2.—*Neutralisation of the Residues from the manufacture of Chlorine; precipitation of Sulphur.*

These residues contain three substances which unite in precipitating sulphur; they are hydrochloric acid, free chlorine, and ferric chloride.

Into one pit is brought a mixture, in convenient proportions, of the two yellow liquors so as always to maintain a slight excess of sulphurous acid and the acid residues from the preparation of chlorine. The moment of neutralization is known by the precipitated sulphur, which at first is pure yellow, becoming grey from the presence of a trace of sulphide of iron. The precipitated sulphur is very abundant, and of such a consistence that it settles rapidly and permits the easy passage of liquids; it is washed on a filter, pressed, and dried.

3.—*Separation of the Iron.*

The preceding operation has neutralized the residues from the manufacture of chlorine; at the same time the free chlorine has disappeared, and the ferric chloride has been reduced to ferrous salt.

According to the process described in the memoir of M. Buquet, the neutralized liquid was pumped into certain reservoirs, where the iron was eliminated by fractional precipitation by adding gradually a solution of the sulphuretted yellow liquors to the mixed chlorides of iron and manganese, a precipitate was thus obtained of sulphide of iron containing 45 per cent. of sulphur, and equalling *pyrites smalls* for the manufacture of sulphuric acid. This manufacture of sulphide of iron has been stopped, as the ashes resulting from the roasting are of no value, and form a cumbersome residue; moreover, the sulphide of iron in the form of paste has a singular consistency which may be compared to that of tar or of a fatty body; it is washed and drained with difficulty, and attaches itself to all bodies with which it comes in contact, and it is only removeable by excessive and violent washing. The workmen show a certain unwillingness to work with it. It is therefore preferable to employ the sulphuretted yellow liquors for the preparation of the sulphide of manganese,

which is more advantageous and an easier operation, and the iron is eliminated by sending into the liquid a little waste mixed with caustic lime; the precipitate, which is a very impure mixture of sulphide and oxide of iron, is added to the total mass of waste and serves to induce oxidation.

4.—*Precipitation of Sulphide of Manganese.*

The liquids coming from the preceding operation contain only the chlorides of manganese and calcium. After clarification in a special tank, the sulphuretted yellow liquors are added, and a beautiful rose red precipitate of manganous sulphide free from iron but mixed with sulphur is obtained. The use of yellow liquors containing hyposulphite is carefully avoided in this operation because the latter compound does not precipitate salts of manganese, and the corresponding sulphur would be lost.

When the precipitate is formed, it is allowed to settle, and the clear liquid is decanted and allowed to flow into the river; the sulphide of manganese is collected, washed, drained, and dried on warm plates.

The preparation of sulphide of manganese on the large scale permits of the close study of the chemical properties of this body.

As it is obtained at Dieuze, it contains 58·6 per cent. of sulphur; sulphide of carbon dissolves two-thirds of the sulphur if it has been dried rapidly, there is therefore only one third of the sulphur combined with the manganese.

According to these data it would contain—

Sulphur - - - -	40
Manganous sulphide - -	55
Oxide of manganese - - -	5
	100

approximately 3 atoms of sulphur for 1 of manganese; whence we may conclude that the sulphuretted yellow liquors contain tersulphide of calcium. Exposed to the air it becomes brown rapidly. This colouration is due to a remarkable phenomenon of oxidation effecting the separation of the sulphur from the manganese which forms an oxide. This combustion is continuous, and, from the observations of M. Hofmann, the final result would be the total decomposition of the sulphide; no sulphate is formed. The quantity of heat disengaged during this exposure to the air is considerable; it accumulates sufficiently from fragments of sulphide in heaps 2 to 3 decimetres high, so that after five minutes the heat disengaged is sensible to the hand, and at the end of twenty minutes it is sufficient to inflame the sulphide. At Dieuze there has been constructed a small furnace which permits of this experiment being conducted on a larger scale, and to give most striking evidence of this singular fact. This furnace is a cylindrical space about 1 metre high; the grate is a simple arch of dry

stones; it communicates with a sulphur burner which receives the products of combustion. This small furnace is charged from above with large pieces of sulphide, the aperture is closed with bricks luted with clay. The feeble draught of the sulphur burner produces a current of air sufficient to traverse the interstices of the grate; the oxidation commences; the temperature being elevated, in five minutes the sulphide catches fire, and in a few moments the mass is at a bright red heat, which is maintained so long as there is any sulphide remaining.

This proneness to combustion necessitates precautions to avoid accidents. It has been observed that the sulphide when in the form of powder does not inflame spontaneously, no doubt because the air then penetrates too slowly. If it is wished to place the sulphide in heaps, the workmen must crush the lumps with his shovel; under these conditions no ignition has been observed. However, it is rare to have any considerable quantity stored, the sulphuric acid manufacture consuming it as it is produced.

5 and 6.—*Combustion of the Sulphide of Manganese; Utilization of the Ashes.*

As we have just seen, there is no difficulty in burning the sulphide of manganese; this combustion is performed simply in the furnaces in which Sicilian sulphur is burned, the sulphurous acid being conducted to the lead chambers.

The residue from combustion contains, according to M. Hofmann,—

Manganous sulphate - - -	44·5
Binoxide of manganese - -	18·9
Protoxide - - - - -	36·6

The weight of the ash is half the weight of the sulphide used.

The manganous sulphate produced in this reaction would appear to be a serious obstacle to the employment of sulphide of manganese; its formation causes a loss of sulphur, and from its solubility it is as inconvenient a residue as the chloride. This difficulty has been overcome by so ingenious a process that not only is the loss of the sulphuric acid corresponding to the manganese sulphate avoided, but the oxide of manganese is in a great measure recovered. The process described in the memoir presented to the Industrial Society has been modified; the sulphate of manganese is no longer separated by washing. It has been remarked that the presence of oxide does not at all change the conditions of success; at one step the cost of evaporating the solution of the sulphate has been avoided, and a superior yield of binoxide has been obtained.

The ash of the manganous sulphide is mixed with an equivalent quantity of nitrate of sodium; this mixture, heated in a sulphur or manganous sulphide furnace, disengages the nitrous fumes necessary for the formation of sulphuric acid. The residue from the calcining is a mixture of neutral sodium sulphate and oxide

of manganese, containing 55 per cent. of the binoxide, and equalling the native manganeses. In certain cases it may be advantageous to the manufacturer to produce a richer oxide; pure manganous sulphate is then employed, and an oxide containing 70 per cent. of binoxide is obtained.

To recapitulate: the process adopted at Dieuze converts two troublesome and offensive residues,—

1st. Into a solid residue, composed of sulphate of lime, carbonate of lime, oxide of iron, and oxide of manganese, substances which are insoluble and inoffensive.

2nd. Into a liquid residue, containing part of the calcium, and all the chlorine from the manganese residues, in the form of calcium chloride. This neutral salt, dissolved in a certain quantity of water, is inoffensive, and may with impunity flow into a river.

It furnishes as useful products:—

1st. Sulphur either free or combined with manganese.

2nd. An oxide of manganese, which can be used for the preparation of chlorine.

It will be seen that this process still produces residues; it does not, therefore, attain to the ideal of chemical manufacture, but these residues, not being hurtful to any manufacture, will not readily induce litigation.

Some attempts have been made at Dieuze to utilize the calcium chloride.

The production of pure calcium sulphate by the action of sodium sulphate was tried; the fibrous structure of this body seemed to indicate it as a substitute for kaoline in the paper manufacture; but this product has not been accepted hitherto, and this part of the Dieuze process still remains a proposal.

. . . .

Two useful products have been obtained, viz., sulphur equal to 36 per cent. of the total quantity in the waste, and sulphate of manganese, which contains a further amount of from 8 to 10 per cent. of that substance.

Before entering upon the financial part of this report, it is necessary to examine the value of the products obtained.

Grey sulphur contains about 90 per cent. of pure sulphur; it is, therefore, almost equal to Sicilian sulphur, which contains from 2 to 5 per cent. of impurities.

On the Regeneration of the Sulphur employed in the Alkali Manufacture, as conducted at the works of Messrs. Charles Tennant & Co., St. Rollox, by the "Mactear" Process.

Read before Section B, British Association, Plymouth, 7th Aug. 1877.

The "Mactear" process owes its origin to the great nuisance produced by the natural oxidation of the enormous heaps of

alkali waste, and its subsequent lixiviation either by rainfall or by springs under the heaps, and differs in the first instance from Mond's process, in that it proposes simply to deal with the drainage liquors from the deposits, and not by any special separate treatment of the waste.

The principle on which all these processes for the recovery of the sulphur have been based is identical, and lies in the decomposition of sulphuretted hydrogen by sulphurous acid, or such decompositions as are to all intents and purposes equal to this.

It is of course necessary that the lime sulphur compounds must be in such proportions that, on the addition of hydrochloric acid with proper precaution, there shall be practically no evolution of sulphuretted hydrogen; and in Mond's process it has been found extremely difficult to obtain in practice liquors of the required composition, and if the workmen are at all careless there is apt to be a considerable evolution of sulphuretted hydrogen.

In the "Mactear" process the apportionment of the various sulphur compounds is very simple, and the evolution of sulphuretted hydrogen, except in cases of the most gross carelessness, is very slight indeed. Although this process has until very recently only been in use at the works of Messrs. Charles Tennant & Co., at St. Rollox, yet by it more sulphur has been recovered than by any other process hitherto introduced.

The heaps of alkali waste at the St. Rollox Works have been accumulating for over 40 years, and are chiefly deposited on the surface of an old "bog" or "peat moss," which has been formed in a natural basin in sandstone rock. This bog is of large extent, and contains many springs of water, which, rising up under the waste, dissolve out the soluble sulphur compounds, and give rise to a large flow of what is commonly called "yellow liquor," which is a complex sulphide of calcium, holding also in solution free sulphur. This liquor was for many years allowed to flow with the natural drainage of the land into a stream called the "Pinkston Burn," which, after traversing a considerable portion of the city of Glasgow as a covered sewer, falls into the river Kelvin at some little distance from its junction with the Clyde. This burn in its course receives liquid refuse of all sorts other than mere sewage, notably refuse from distilleries, and these being acid gave off from the sulphide of calcium liquors sulphuretted hydrogen in such quantities as to give rise to a most intolerable nuisance, of which the public had good reason to complain.

The writer's two predecessors in the management of the works of Messrs. Charles Tennant & Co., the late Messrs. C. T. Dunlop and John Tennent, used their best endeavours to abate or remove the cause of complaint, but in the then state of knowledge it was not found possible to overcome it, although a large sum of money was expended in the attempts.

An effort to abate the evil by intercepting the springs of

water which were supposed to exist under the deposits was made, a shaft being sunk to the sandstone rock some 40 or 50 feet in depth, and a series of mines or galleries were then driven in various directions, extending in one direction to nearly 300 yards, and following up all water sources that were met with. A large amount of water was thus drained off, and it was pumped out of the mine and run away. This was continued night and day for years, and must no doubt have decreased the amount of sulphide of calcium liquor, which, however, existed still to the extent of about 30,000 gallons per day, of from 11° to 14° Twaddell.

The rainfall of Glasgow being about 42 inches per annum, and one inch of water being equal very nearly to 100 tons per acre, the amount of drainage due to the rainfall alone, supposing half the total amount of rain to pass through the mass of waste (which is of rather a porous nature), would be very nearly 1,300 gallons per acre. The deposits covered at this period about 10 acres, so that there would be equal to at least 13,000 gallons per day due to rainfall alone.

The damp climate of Glasgow thus adds to the difficulties in the way of utilizing the waste and prevention of nuisance.

In the year 1864 an iron pipe of some 9″ diameter was laid direct from the St. Rollox Works to the River Clyde, and the sulphide of calcium liquors were thereafter run away by this channel, a large reservoir being constructed to enable the liquid to be stored up, so that it might only be allowed to flow away into the river while flooded with rain, which in our climate is not seldom.

Still the nuisance, although it had been removed altogether from the district in which it had formerly given such cause of complaint, was only transferred in a lessened degree to another, and serious complaints were made as to smell, and also as to an alleged action of the water of the Clyde on the copper sheathing of the ships which lay in the river. The late Professor Anderson made an investigation, and prepared a long and interesting report on the subject for the Clyde Trustees in 1865, and thereafter, year by year, pressure was brought to bear on the Messrs. Tennant by the authorities, in order to force them to take such steps as were possible to prevent nuisance arising from this drainage.

And here it is worth considering one of the greatest difficulties in dealing with a question of this kind. It is this:—

The drainage comes chiefly from heaps of waste which have been some time deposited, not from the fresh waste, and if the usual cry of the aggrieved public were to be acted upon, and the works abolished or forced to remove, the drainage would still remain, and continue for years to be as great a nuisance as before; indeed, were an alkali work compelled to close on account of its waste heap drainage nuisance, there would be no hope whatever of the nuisance being reduced for years to come. On the other hand, by such a process as that now in use at St. Rollox, the alkali work, while it produces hydrochloric acid, can utilize this

waste drainage liquor without nuisance; and thus the best means of removing cause of complaint of alkali waste drainage, is by encouraging the alkali works to remain and to undertake the production of sulphur.

In the year 1867 the writer's firm erected plant for the sulphur recovery process of Mr. Mond, which we proposed working on a modified system, in which the drainage liquors were to be used instead of water for lixiviating the oxidised waste.

So far as the production of sulphur was concerned, this process succeeded admirably, but the evolution of sulphuretted hydrogen when the liquors were not of exactly the correct proportions for decomposition, and also that given off during the oxidation of the waste, which, in the large scale on which the process was employed at the St. Rollox Works, was considerable, caused serious complaints in the immediate neighbourhood of the works.

The very large amount of plant required also, and the fact that it was not found possible to work up by it all the drainage liquors, induced the writer to again carefully study the subject in all its bearings; and after a long series of experiments, many of them, like those of former workers in the same direction, failures, he succeeded in developing the process which has been so successfully worked at St. Rollox, and bears his name.

As has been said, the principle of all the processes for the recovery of sulphur from alkali waste lies in the mutual decomposition of sulphuretted hydrogen and sulphurous acid.

The "Mactear" process depends on the decomposition of the sulphides of calcium by hydrochloric acid, in the presence of a source of sulphurous acid.

The process has various modifications, each of which is applicable under special circumstances:—

1st. The drainage liquor usually called "yellow liquor" is mixed with a small proportion of lime, and then treated with sulphurous acid, which it absorbs, giving a small quantity of sulphur. The liquid containing this sulphur in suspension is then decomposed at a temperature of about 140° Fahr.

This method gives good results, but is difficult to regulate, and is subject to the same objection as Mond's process, in that it is difficult to regulate the composition of the liquors, even when only a portion of the yellow liquor is treated with sulphurous acid, and then mixed with the remaining portion and hydrochloric acid.

It is also, in consequence of this difficulty, apt to give rise to an evolution of sulphuretted hydrogen, and cause a nuisance.

2nd. The modification actually worked for the past five years is that of using a solution of sulphurous acid in water. This is obtained either from pyrites, or from the refuse sulphur from the process.

The condensing towers are built of wood, common flooring boards, well jointed, and bound with iron corner-pieces and

tie rods. These towers, after five years' use, seem at this date almost as good, and the wood as fresh, as when new.

These towers are filled with coke in three stages, strong cross joints dividing the tower into three divisions. A tray, with a large number of little tubes of lead, covered over with lutes to avoid entrance of air, divides the water into fine streams, and the sulphurous acid gas is then lead up one tower, down to the bottom, and up another tower.

The solution of sulphurous acid in water, in practice, is only of about 2° Twaddell, and in this lies the worst feature of this modification of the process, viz., the heating to the proper temperature for decomposition of such a large bulk of liquid.

The solution of sulphurous acid is led, by means of a wooden shute, to the decomposing vessels, and is mixed on its way with a stream of the yellow liquor or sulphide of calcium; it then runs into the decomposing vessel, where it is met by a stream of hydrochloric acid, the whole kept carefully at as near 145° Fahr. as possible. With moderate care, little sulphuretted hydrogen is evolved, and the decomposition is regulated in the easiest manner by a very simple means of testing:—A burette is fixed to a wooden upright, and filled with the yellow liquor, a sample is drawn from the decomposing vessel, a drop of solution of sulphate of iron added, and then the yellow liquor run in from the burette; the number of divisions required to blacken the solution indicate the acid still present.

The sulphur is allowed to settle, and the clear liquor run off through a catch pit, so as to retain any sulphur that might otherwise be lost; and after some 5 or 6 operations, the sulphur sludge is run off into a drainer.

After draining into a stiffish mud, it is transferred to a melting vessel, where it is melted by steam; and, if necessary, the arsenic removed by an application of the well-known fact that alkaline sulphides dissolve sulphide of arsenic. This process was first applied at St. Rollox in 1869, while working Mond's process, and has been adopted by almost all those manufacturers who recover sulphur. It has the drawback, however, that it also removes a quantity of sulphur, which is of course just so much loss.

The plant required is simple, and, looking at the results obtained, very inexpensive.

It consists of:—

1*st*. Pumping arrangement and cistern for the yellow liquor.
2*nd*. Kilns for burning pyrites or sulphur, and producing SO_2.
3*rd*. Condensing towers, and water supply.
4*th*. Steam boiler.
5*th*. Wooden decomposers, with stirring gear.
6*th*. Wooden drainers for the sulphur.
7*th*. Steam melting arrangements.

And the following is an estimate of the cost of the plant now at work at St. Rollox:—

MACTEAR'S SULPHUR RECOVERY PROCESS.

COST OF PLANT.

To produce 30 to 35 tons weekly.

	£	s.	d.
Sulphur burners - - -	38	0	0
Cast-iron tunnel - - - -	130	0	0
Lead tunnel - - -	22	0	0
Scaffolding for pipes - - -	16	0	0
Condensing towers - - -	162	0	0
Pipes and fittings, &c. - - -	35	0	0
Wooden decomposing vessels -	163	0	0
Engine and gearing - - -	160	0	0
Valves, runs, taps, &c. - -	64	0	0
Water tank - - - -	24	0	0
Steam and water pipes - -	50	0	0
Pumping engine - - -	40	0	0
Steam boilers - - -	600	0	0
Brickwork and fittings - -	110	0	0
Melters and fittings - - -	151	0	0
Square draining tanks - -	120	0	0
Roofs - - - - -	134	0	0
	£2,019	0	0

All this plant is substantially erected, and likely to last for many years, with ordinary repair.

It is capable of making 35 tons of sulphur weekly, from yellow liquors of about 11° Twaddell; when less than this strength, the increased bulk of liquid prevents the necessary amount being worked in the decomposers.

The following statement shows the cost of manufacturing one ton, with the consumpt of coals, acid and pyrites:—

DETAILED COST OF ONE TON OF SULPHUR BY "MACTEAR" PROCESS.

	Cwt.	Qr.	Lb.	Rate.	Cost.
Pyrites Sulphur - - -	8	0	25	39/	16·03/
Salt - - - - -	35	1	18	16/	28·33
Vitriol - - - -	29	3	27	30/	45·00
Coal - - - - -	114	2	7	4·4/	25·20
Repairs - - - -	—			—	4·00
Wages - - - -	—			—	38·50
					157 06
Off Sulphate of Soda - -	39	0	21	49/	96·01
Nett cost of one ton of Sulphur -	—			—	61·05/

It will be seen that the cost, which is based on an experience of five years, and extracted from the annual accounts of my firm, shows that a ton of sulphur has been made for an expenditure of about 61/ per ton. In this nothing is charged for hydrochloric acid; it is usual to treat hydrochloric acid in this way when used in the manufacture of bleaching powder, and therefore it is the proper way to compare the results on the same basis.

We may assume that the Weldon process is the one by which bleaching powder is now almost universally made, and that it requires in the usual practice the acid of

55 cwt. of salt to 20 cwt. of bleaching powder.

If we take the lowest cost of bleaching powder as being

5*l.* 10*s.* per ton,

and compare it with sulphur, when

36 cwt. of salt yields 20 cwt. of sulphur,

at a cost of, say 3*l.* 5*s.*

we have—

	Cost.	Price.	Margin.
Bleaching Powder -	5*l.* 10*s.*	7*l.* 0*s.*	1*l.* 10*s.*
Sulphur - -	3*l.* 5*s.*	6*l.* 10*s.*	3*l.* 5*s.*

Or for each one ton of salt decomposed, the profit obtained will be—

In the case of bleaching powder,

say 11*s.*,

While in the case of sulphur it will amount to,

say 36*s.*,

A larger profit in favour of the manufacture of sulphur to the extent of

25*s.* per ton of salt

used in producing the acid required for its manufacture.

These figures will of course be modified from time to time by the market price of the articles.

It will at once be seen that the manufacture of sulphur by this process is a much more profitable means of using hydrochloric acid than is the manufacture of bleaching powder, and I am of opinion that it will long continue so, because, in the first place, Sicilian sulphur cannot be reduced much below its present price without shutting up some of the mines, and reducing considerably the production there; and secondly, the effect of the Alkali Acts and recent Royal Commission has been to increase the manufacture of bleaching powder, and by an excess of production over demand, to keep the price at a point at which it is no longer remunerative to the manufacturer.

So far as the question of removal of nuisance is concerned, this process has been amply successful in dealing with the sulphide of calcium liquors which used to flow into the Clyde from our works; and on the last occasion on which a complaint of smell was made, it was traced to the escape of coal gas, which, owing to some accident at the city gas works, had been allowed to pass into the pipes unpurified

for some little time; the gas escaped into the sewer, and a series of complaints of the frightful nuisance of those chemical works was the result. As the complaints came not only from the neighbourhood of the works and the sewers in connection therewith, but also from the other side of the river, the town authorities traced the complaint to its real source, and exonerated us from all blame in the matter.

3rd. The third modification of this process is intended for use when the liquors are very weak in strength, say 5° to 8° Twaddell, in which case the cost of fuel becomes much enhanced.

It consists in obtaining a stronger solution of sulphurous acid by the production of a bisulphite of lime, or at least of a solution of sulphite of lime in sulphurous acid, which is used just as the sulphurous acid solution in the 2nd modification is employed.

As the old waste contains large quantities of sulphite of lime, it is utilized in this modification of the process by grinding it in water to a milk and treating this with sulphurous acid; thus obtaining a solution of sulphite of lime in sulphurous acid, and thus reducing considerably the amount of sulphur required to form sulphurous acid.

More hydrochloric acid is of course required by this method, but it has great advantages to recommend it.

There can be no doubt that the application of one or other of the modifications of the "Mactear" process to the waste drainage, from the heaps at the great centres of the alkali trade, such as Widnes and St. Helens, would reduce very greatly the nuisance complained of there.

The St. Helens manufacturers have recently decided not to put any acid drainage into the celebrated Sankey Brook, and this will lead to its utilization in one way or another. The most probable direction for it to take is that of the manufacture of bleaching powder, an article of which I am sorry to say there is at present a very great over-production.

Were, for instance, a combination of manufacturers along the course of the Sankey Brook to collect the drainage liquors, pump them to a convenient spot (in which my experience of nearly ten years shows there is little difficulty), and treat them with the acid of either one or various works, obtained by arrangement, I am confident the nuisance complained of in that district would be much reduced, and a handsome profit realised by the manufacturers.

The result of this method is a drainage without colour and scarcely scented.

The Solution from the Waste.

The rain falling on the waste brings down oxygen, and the result already mentioned takes place, so that we may have a clear

yellow stream, or with some iron a dark bluish one, which becomes decomposed by the carbonic acid of the air, and gives off sulphuretted hydrogen. If this stream is not kept within bounds, but allowed to overflow the fields, the acid rain falling on such a great surface still further decomposes the sulphide, and more sulphuretted hydrogen is formed,—a very common occurrence. If a stream of water containing acid meets this stream of sulphide, the formation of sulphuretted hydrogen is abundant, and the liquid becomes opaque and yellow from free sulphur. This acid stream is frequently found coming from chemical works where muriatic acid is made.

The sulphur solution is that which nature has formed from the heaps, and which Mr. Mond forms by mechanical oxidation; at least it is so to a great extent. It does not contain the exact amount of hyposulphite to form the decomposition wanted, but by a little further oxidation the proper state may be produced. The two acids, hyposulphurous and hydrosulphuric, do not decompose each other when united to the calcium, but if that base is removed the former acid is decomposed, leaving sulphur to fall, and sulphurous acid to decompose the sulphuretted hydrogen. It is on the solution made by nature from the heaps that Mr. McTear begins his process.

Angus Smith's Process for treating Sulphide Solutions.

The process which I proposed in 1877, or earlier, was not given to the public till 1879. However, the date has been preserved so far that after I had made trials for about a year Mr. McTear was good enough to make an experiment for me, and the account of them is dated 8th August 1878. (See Report for 1877 and 1878, p. 38.) I say this more particularly because of some mistakes having been made in this respect, and it abundantly shows that I could have taken the idea from no one in any sense. But as ideas grow from their ancestry, and this ancestry I described clearly, I shall repeat the account here.

I have already mentioned that the manager of Mr. Tennant's works told me that he had tried the burnt pyrites for purifying the solutions at the base of the waste heap, and that for a time they came through the iron quite clear; that he had given up the plan, however, as the clearness did not continue. We know, of course, that nothing will continue. The removal of the sulphur from soluble sulphides by hydrated oxide of iron has not been able to make a successful process. The action is slow; and with great quantities only, and by allowing a great space, can it be expected to succeed even with the hydrate. The same slow process must be allowed for the re-oxidation, when the iron will be able to begin its work again.

When I saw from the evidence of Mr. Shaw given before the Noxious Vapours Commission that the drainage from the heaps at the South Shields Works was deodorized by means of

the waste oxide of iron from the manganese solutions, I went to examine the process. I could scarcely call it a finished process, since the matter was merely thrown down and rarely stirred, the chief work being left to the air. I had no faith in the iron from my former experience. I had also tried manganese at the same time, and did not expect sufficient results from that. Something new must be added that I had not known before, and this was found in other processes, namely, blowing air through the solution to supply the oxygen. It was not intended to try the chloride of iron; that, we knew, would act as least by equivalents; it was known also what chloride of manganese would do, since it was proposed as a disinfectant by James Young, F.R.S., and it was only necessary to try the oxide.

With this in view, a solution from the waste heaps was treated with peroxide of manganese, and sulphuration took place immediately, part of the oxygen of the manganese going to form a thiosulphate. The mixture was shaken in a bottle with air, and an oxide of manganese was formed, whilst sulphur fell.

The process was then complete in theory, and it was desired to make it continuous. This was done in a very simple manner. The solution to be freed from sulphur was put into a tall glass vessel, a little of the peroxide of manganese was added, only $1\frac{1}{2}$ gramme to a litre, and air was blown in. This completed the conversion; but it was not yet a continuous process. A syphon was then added to the vessel, one end reaching to the bottom, the other being outside to draw off the purified solution whilst the fresh sulphide entered above. This acted well, but some of the solid matter rose with the liquid and was lost. The mouth of the syphon was then enlarged by adding a small inverted funnel to it, and covering this with calico, so that the liquid came off clean and quite free from any sulphide.

As a sanitary process it is perfect, but is it so as a manufacturing process?

The first quantitative trial was made on a mixed sulphide of calcium obtained by heating lime milk with sulphur. To this solution 1·025 gramme of peroxide of manganese was added, and air passed through. After $3\frac{1}{4}$ litres had been oxidized, the precipitate gave 2·89 grammes of sulphur.

Next 1 gramme manganese peroxide oxidized 9 litres of sulphide of calcium solution, the precipitate having 17·5 grammes of sulphur, or 72·3 per cent.

3·9 grammes peroxide of manganese added to waste liquor, or liquor from the soda waste heaps, containing 17·6 grammes of sulphur per litre, diluted 20 times or to ·88 grammes sulphur per litre in sulphide, and 1·54 as hyposulphite, was oxidized continuously for three weeks and a half. The supply of liquid was at first $\frac{1}{2}$ a litre per hour, but at last it rose up to 2·7 litres. 140 grammes of precipitate were obtained containing 77 per cent. of sulphur. The remainder was principally carbonate of lime. 160 litres altogether of the dilute solution were used, giving

67·6 grammes per 100 litres, or 108 grammes of S out of 140 in the original solution.

Another sample of drainage liquor from Widnes gave ·14 grammes from 1·8 litres, or only 7·7 per 100 litres.

The precipitate of sulphur is mixed with carbonate of lime, and, unless carefully washed, some hyposulphite, also with a high oxide of manganese when thoroughly oxidised by passing an excess of air.

It is not often, however, that the exact numbers quoted are obtained, because some manganese remains with the sulphur. This is no great objection if the sulphur is to be burnt, as the sulphide of manganese burns readily, at least when tried on a small scale, and leaves a porous friable mass which is capable of being used again, and this could be repeatedly done were it not for the lime remaining, which gradually increases. If the lime were removed by acid this would introduce a feature which it was desired to avoid, but the amount of acid although small might be saved by throwing away the whole, the manganese being so small in amount in comparison to the sulphur gained.

It is also to be remarked that the process has never succeeded in strong solutions. That which usually flows from the heaps requires to be diluted until the amount of sulphur, as in a sulphide, is equal to one-tenth per cent.

This is an objection, as water must be added; but it is not a great evil, since the supply of fresh liquor may be proportionately small. It demands that the vessels be larger, and necessitates more pumping than would otherwise be required.

The reason that the process is not successful in strong solutions is, at least partly, that the sulphur is re-dissolved as soon as precipitated. It has already been said that the sulphide dissolves sulphur readily.

A solution of sulphide of calcium, sodium, or barium gives off sulphuretted hydrogen when common air is passed through it. It is slowly oxidized. Three hours were required to destroy the sulphide of the first, using a solution of the same strength as that taken to compare the oxides of iron and manganese. The sulphur is partly precipitated. An experiment comparing the use of air alone, and air with oxide of manganese, gave—

With air alone - - -	73
With oxide of manganese -	582

In the first case sulphuretted hydrogen is given off, not in the second.

Calculation for Work on a large scale.

Some idea of the amount of work to be done may be estimated in this manner: let us suppose an acre to receive 537,600 gallons of rain annually after deducting one-third for evaporation; and let us suppose this drainage to be of the strongest kind that flows

from waste. Then, judging from the size of the vessels used on a small scale, a vessel holding 1,000 gallons would be sufficient to pass 1,200 gallons through it purified every 12 hours. This would require to be in action for 224 days, night and day, to overtake the drainage. This is not a supposition that strains us much; the amount of sulphur obtained from such a solution as is here spoken of would be, according to the longest experiment made, 1·76 per cent., or 63·36 tons, equal, at 6*l.* a ton, to 380*l.*, to pay for the working, an amount quite sufficient but not highly remunerative. In the case of weaker solutions the amount of sulphur would be less, but the time required would be less also. Some of them are weak enough to require no dilution. The exact expense and the settlement of the many possible questions I cannot of course foresee.

Mr. Weldon has used air for oxidising sulphide of iron, but not manganese with sulphides in solution, and I may state that I have no desire to take from him the credit of using air, although my idea came in the way represented.

The chief objection to the process is that the sulphur of the hyposulphite is not precipitated. To do this would require the aid of Mond's process.

Sulphide of Barium with Oxides of Manganese.

The action of the manganic oxides on the calcium sulphides induced me to try them on barytic sulphides, and here is a result with three sets of experiments.

The simple CaS, as obtained by decomposing sulphate of lime with C in the fire, was found to be dissolved to the extent of 1·3 per cent. If allowed to stand free from air no change is perceived. If shaken with air or peroxide of hydrogen the colouring is immediate.

The result, at any rate in the heaps, is, that by oxidation a mixture of sulphide and hyposulphite is formed, but the inquiries on the sulphates now show that oxygen may be obtained from them without the external air.

Glasgow, 8th August 1878.

Dr. Angus Smith, F.R.S., &c.

I have now the pleasure to send you the remaining details of the experiments on the oxidation of the bog liquor by air and manganese, regarding which I sent you the details of the first experiments on the 6th of May last.

3rd Experiment.—On the oxidation of yellow liquor draining from alkali waste by means of a small proportion of manganese oxide.

Details of Experiment.

Filled oxidizing vessel $\frac{2}{3}$ full of water, added a small quantity of black oxide of manganese (prepared by Dunlop process), and

turned on the current of air from a blowing engine; kept a small stream of yellow liquor constantly running into the oxidizing vessel at the rate of about 2 gallons per hour.

At this rate the air could not quite oxidize it as it ran in; but as, for sundry reasons, it was only run in during the day while the air was kept on night and day, the oxidation was complete enough in the morning; in fact in two cases the manganese had been raised to the black colour, indicating its oxidation to the state of peroxide.

Measurement of liquors.—The fresh liquor was carefully measured in a cast-iron cistern made specially for measuring purposes, and the oxidized liquor was also carefully measured in a similar cistern.

Each morning, after the complete oxidation of the liquor in the oxidizer, the air was turned off, the precipitate allowed to settle, and about $\frac{1}{3}$ of the liquor run off and measured. A fresh amount of liquor was then allowed to flow slowly into the oxidizer, while the air was again turned on. This alteration was carried on until there had been used 216 gallons of yellow liquor. Samples were taken from each operation, and the amount of the sulphur compounds estimated. The precipitate was at the completion of the experiment washed and dried, and its sulphur contents also estimated.

The following give the results:—

Yellow liquor used 216 gallons at $8\frac{1}{2}°$ Twaddell.

Containing:—

		Lbs.
Sulphur as hyposulphite of lime	-	1·015
„ sulphate of lime -	-	·712
„ sulphides of calcium	-	53·569
Total sulphur	-	55·296

Manganese used 10 lbs., containing 68 per cent. MnO_2 (Dunlop's recovered black oxide).

Oxidized liquors:—

421·8 gallons of $4\frac{1}{2}°$ Twaddell.

(The specific gravity varied from 1° in the beginning to $6\frac{1}{2}°$ at the end of the whole experiment.)

Containing:—

		Lbs.
Sulphur as hyposulphite, CaS_2O_3	-	34·377
„ sulphite, $CaSO_3$ -	-	1·350
„ sulphate, $CaSO_4$ -	-	·506
Total sulphur	-	36·233

No Sulphide.

Precipitate :—

It weighed wet 52 lbs., and contained :—

		Lbs.
Sulphur as sulphate $CaSO_4$ - -		1·235
" sulphide MnS - -		1·940
" free sulphur - -		15·140
		18·315

	Lbs.	Lbs.
Total sulphur started with - -		55·296
" at finish of experiment in solution	36·233	
" at finish of experiment in precipitate	18·315	
		54·518

0·648 lbs. lost.

This loss occurs by evolution of H_2S, spills of liquor, and inaccuracies in the measurement.

Calculated on to percentage results are—

For 100 parts of sulphur started with there has been obtained—

In solution - - -	65·65%
In precipitate - -	33·18
Lost - - - -	1·17%
	100·00

In the precipitate there exists—

As available sulphur, say for melting out for sale - - -	27·3%
As sulphide - - -	3·64%

Lime :—

The lime CaO in the yellow liquor was equal to 43·9 lbs. CaO, and the CaO in oxidized liquor amounted to 37·2 lbs. The difference = 6·7 lbs. CaO had been thrown down as carbonate or sulphate. All the lime as carbonate is equal to at least two equivalents of free sulphur.

6·7 lbs. CaO = 15·26 per cent. of the CaO in original liquor. Say that the lime equals two equivalents of sulphur $\frac{6{\cdot}7 \times 32}{28} = 7{\cdot}66$ lbs. sulphur. Then, as total sulphur precipitated was equal to 18·315 lbs., and the sulphur equal to loss of CaO in liquor was equal to 7·66 lbs., we have $\frac{7{\cdot}66 \text{ lbs.} \times 100}{18{\cdot}315 \text{ lbs.}} = 41{\cdot}8$ per cent. of the sulphur precipitated, due either to the formation of

sulphate or carbonate of lime. As the amount of sulphate is not high, it would seem as if the CO_2 had done nearly as much work in precipitating the sulphur as did the oxidation and reduction of the manganese.

The amount of air used was enormous compared with the work actually done.

From all the results obtained I would be much inclined to think that if gases such as those from a chimney were forced through DILUTE yellow liquors (perhaps washing first to get rid of acid vapour) the results would be from every point of view much more satisfactory. I intend trying this, and will report to you the results.

Yours, in haste,
JAMES MACTEAR.

The amount of free sulphur obtained by Mr. McTear is less than that obtained by me. He used a large excess of air, and this seems to explain much. If we use as little oxygen as possible we limit the amount of thiosulphate formed. If we use no air, but only the lower oxide of manganese or carbonate of manganese, for example, we obtain with difficulty any result. Some of the solutions have stood for weeks with oxide of manganese without losing the yellow colour, but those with carbonate of manganese are decomposed more rapidly.

Abstract. (p. 45 of Report.)

MnO, protoxide of manganese, added to the solution without air, the CaS_2 is not decomposed.

If MnO_2 or any oxide above MnO be added the sulphur is taken down rapidly and the calcium is oxidized, but no sulphur, so that no thiosulphate is formed.

No sulphurous acid or sulphite is formed.

No sulphuric acid or sulphate is formed.

If this sulphide of manganese is exposed to air it becomes oxidized, and sulphur is thrown out in a free state.

If air is passed through the liquid in which the sulphide of manganese lies oxidation takes place, and oxide of manganese is formed, at first white and afterwards dark, according to the continuation of the current of air. During this oxidation there is hyposulphite formed by the oxidation of part of the sulphur.

Carbonate of manganese may be used instead of oxide.

If air is passed through the sulphide solution by itself hyposulphite is formed, and some sulphur is deposited, and the action is slow, but there is still some, and H_2S is given off.

When solutions of sulphide of sodium were deoxidized with manganese (p. 36 of Report) a constant formation of hyposulphite of sodium took place.

Gas Lime.

It was then held possible that the same process might apply to the sulphuretted lime of the gasworks so much complained of, and it was found that by treating with water, and removing the sulphur from the water solution by means of manganese, there is obtained a liquid quite free from smell, and a considerable supply of that sulphur which in part had existed in the gas is precipitated in a free state, and will probably be found extremely pure.

Apparatus used.

A drawing is given of the apparatus by which the experiments were made in the laboratory. I have not made any attempt to use larger apparatus, but I should not suppose that it would be well to imitate this particular form. It is probable that a revolving water-wheel raising the fluid mixed with the manganese and allowing a stream of gas to pass through would present a very much larger surface than any gas forced into the liquid in proportion to the power applied. If, however, pressure is important the advantage would be against the wheel; and pressure is of advantage, as the experiments show, if not too expensive.

Since writing the above I have used a small dash wheel to make spray, and have very much quickened the process.

When this was published I received a visit from Dr. Storer, of Glasgow, a gentleman whom I had not seen before. His object was to show me an apparatus which he considered well adapted for mixing the air with the solutions to be aerated. He had also new views regarding the substances which might be aerated. He had already been interested in aeration, and had been applying his knowledge successfully to the treatment of oils, so as to make drying oils. He had also been oxidising sulphates and chlorides of iron after adding lime.

He also spoke of applying the process to the oxidizing of manganese in the Weldon process, and in oxidizing sulphur liquors in soda works, a purpose also laid down in my report.

This, of course, was interesting to me, but I was at the time engaged in examining questions relating to water, and it was in this department that I was inclined chiefly to renew my interest.

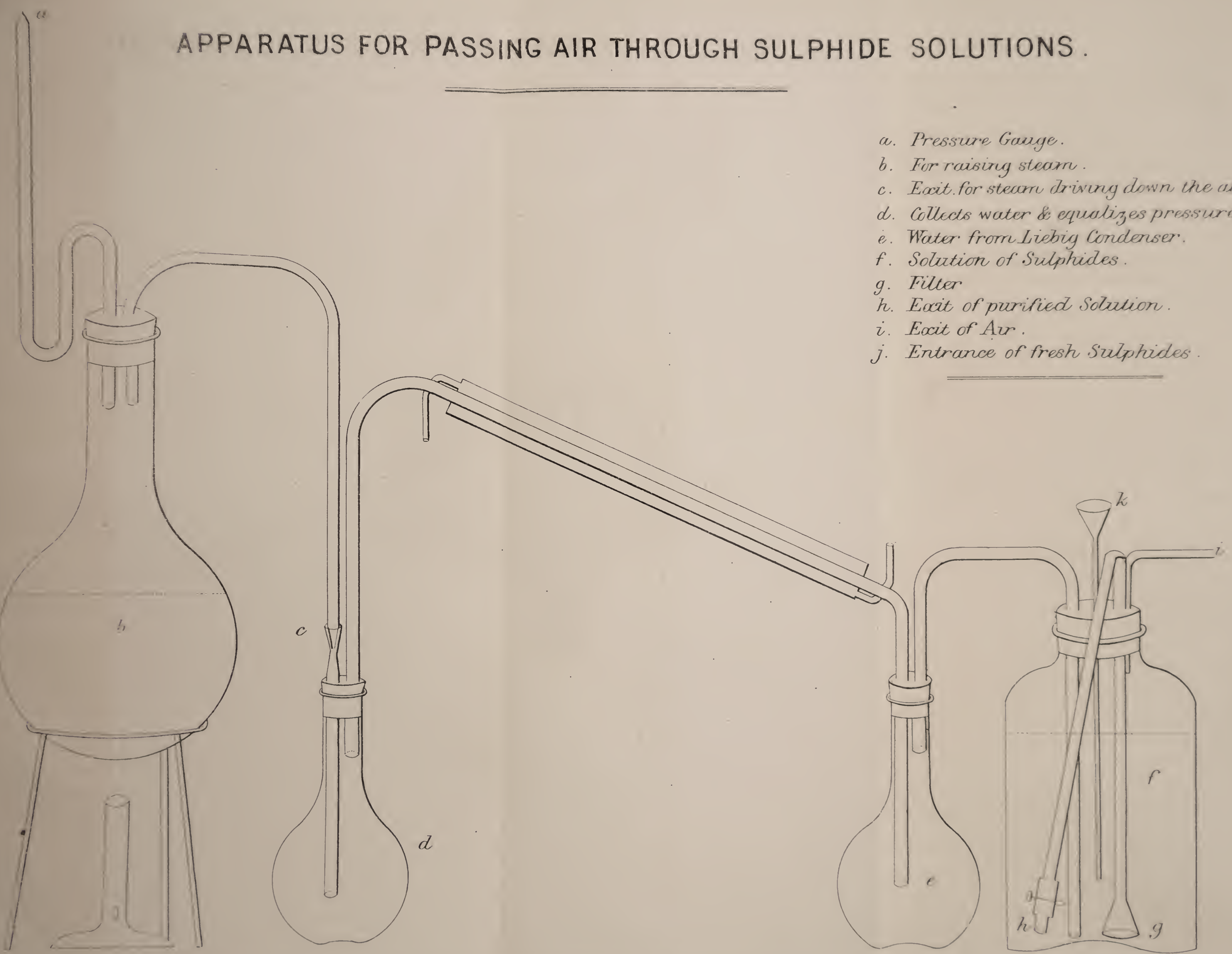
Messrs. Helbig and Schaffner's Process: from Professor Lunge's work on "Sulphuric Acid and Alkali."

Complete recovery of Sulphur and Lime from Tank-waste.

"We shall conclude this chapter by describing in *extenso* the new process of Schaffner and Helbig (patented in England, March 9th, 1878), which, if it succeeds as well in the long run as it has done hitherto, seems destined to put the final touch to

APPARATUS FOR PASSING AIR THROUGH SULPHIDE SOLUTIONS.

a. Pressure Gauge.
b. For raising steam.
c. Exit for steam driving down the air.
d. Collects water & equalizes pressure.
e. Water from Liebig Condenser.
f. Solution of Sulphides.
g. Filter
h. Exit of purified Solution.
i. Exit of Air.
j. Entrance of fresh Sulphides.



Dangerfield Lith 22 Bedford St Covent Garden

Leblanc's process, since it entirely does away with the only serious drawback attached to that process, viz., the tank waste.

"The sulphur recovery processes hitherto in use are based essentially on oxidizing the tank waste to a certain extent, dissolving out the sulphur liquor, and precipitating the sulphur by muriatic acid. In the best case, however, only 50 to 60 per cent. of the sulphur are thus recovered; the other 40 to 50 per cent., together with lime, form a new waste, containing undecomposed calcium sulphide along with sulphite and sulphate. This new waste is not a nuisance similar to fresh tank waste; but, owing to its great bulk and its very slight utility, it is a great burden upon alkali works. This will be done away with by the invention of Schaffner and Helbig, which recovers by far the greatest portion of the sulphur and also the lime.

"It is chiefly based on:—

"(*a.*) The applicability of magnesium chloride, hitherto not employed in the arts, to decomposing calcium sulphide, thus:—

$$\text{"I. } CaS + MgCl_2 + H_2O = CaCl_2 + MgO + H_2S$$

(calcium carbonate not being acted upon by $MgCl_2$).

"(*b.*) The recovery of the magnesium chloride by exposing the residue from the first operation (consisting of magnesia, calcium chloride, and the impurities of soda-waste), after driving off the H_2S to the action of carbonic acid, by which calcium carbonate and magnesium chloride are formed, thus:—

$$\text{"II. } MgO + CaCl_2 + CO_2 = MgCl_2 + CaCO_3.$$

A portion of the magnesium chloride can be replaced by the simultaneous action of muriatic acid, by which the separated magnesia is always dissolved again, and again becomes active. This reaction might be applied where an excess of muriatic acid is obtained, and at the same time yields calcium chloride in case the latter is not got otherwise as a by-product. In this case the mud, after being treated with boiling water, is allowed to settle, and a corresponding portion of the clear $CaCl_2$ liquor is drawn off. Of course the action of CO_2 can only recover as much $CaCO_3$ as corresponds to the $MgCl_2$ employed.

"(*c.*) The sulphuretted hydrogen escaping in the first operation is transformed into sulphur by means of sulphurous acid:—

$$\text{"III. } 2H_2S + SO_2 = S_3 + {}_2H_2O.$$

Ordinarily this reaction does not take place as smoothly as the formula would indicate, but, as we have seen before, large quantities of pentathionic (or tetrathionic) acid are formed; and it would fail to be available in this case, as it has done in all previous cases, unless Schaffner and Helbig had discovered a plan for preventing to a great extent the formation of pentathionic acid, or, if the latter has been formed, precipitating the sulphur from it. This consists in the application of solutions of calcium or magnesium chloride, also of other mineral salts and acids.

If aqueous solutions of H_2S and SO_2 are mixed in the proportions expressed by the above equation, a milky liquid is formed, from which, by addition of a solution of calcium or magnesium chloride, a flaky readily settling precipitate is obtained, which corresponds to the theoretical quantity. An excess of one gas or the other is found unchanged in the liquid, and does not interfere with the reaction. It is not known what part the chlorides play in this case, but so much is certain, that an amount of $CaCl_2$ or $MgCl_2$ equivalent to the total sulphur is required.

"The greatest impediment to the application of the mutual decomposition of H_2S and SO_2, which, even more than the formation of polythionic acids, had baffled all previous endeavours in this direction, was the milky state in which the sulphur is precipitated, which prevents its separation of subsidence or filtration. This is completely obviated by the employment of solutions of salts (as stated above), which is the most important feature of the new process.

"The $MgCl_2$ obtained in the second operation is employed for decomposing new quantities of tank-waste, and the calcium carbonate in the black ash mixture.

"The operations are practically carried out as follows; the decomposition of tank-waste by magnesium chloride takes place in a large air-tight iron vessel provided with an agitator, with contrivances for charging and discharging the materials, gas delivery pipes, &c. Here the mixture is exposed to heat. Either the tank-waste is gradually introduced into a charge of $MgCl_2$, or, inversely, the $MgCl_2$ solution is run upon the waste, or both are simultaneously introduced in equivalent proportions. The apparatus must be so arranged that the operation can be arrested at a moment's notice; nor should any H_2S be able to escape into the air. This is prevented by producing a draught from without by means of a chimney, fan-blast, or pump, and by always keeping an excess of SO_2 in the decomposers over and above that corresponding to the arriving H_2S, so that the latter can never be in excess. According to Stingl and Morawski this process is to be explained thus: first magnesium chloride and calcium sulphide decompose into calcium chloride and magnesium sulphide; the latter at once reacts upon the water present, magnesium hydrate and sulphuretted hydrogen being formed.

"The cinders and other impurities of the tank-waste must be removed from the residue remaining after the just described treatment. They cannot be left in the recovered lime, because accumulating they would make it unfit for black-ash mixing. These impurities are completely removed in a very simple manner, either by levigation or by passing the residue through a fine sieve. The cinders, coal excess, limestone, &c., contained in the tank-waste are heavier and coarser than the magnesia separated in the first operation; they amount to 25 or 30 per cent. of the whole dry weight of the tank-waste. The residue thus purified is now treated with more or less impure carbonic acid in order to recover

the magnesium chloride and calcium carbonate as previously mentioned. The way in which this is done will be apparent from the subsequent description of the apparatus.

"The sulphuretted hydrogen from the first operation is now brought into contact with sulphurous acid and a solution of calcium or magnesium chloride, which can be done either in tubs or towers. In the latter case the H_2S should be introduced at the bottom of the tower, the SO_2 a little higher up. The precipitated sulphur settles down with striking rapidity, owing to the action of the chlorides; it is separated from the liquid by decantation or filtration, and the same solution used over and over and over again for running down in the tower. The gas pipes must be easily accessible from without, for rapid cleaning. The requisite SO_2 is made by burning pyrites, sulphur, or sulphuretted hydrogen, or taken from any metallurgical process; it is either conveyed directly into the decomposer, or first condensed in an ordinary acid condenser to a solution of SO_2 in water, or in a solution of $CaCl_2$ or $MgCl_2$.

"This process is applicable not merely to tank-waste, but also to calcium or barium sulphate after their previous reduction to CaS or BaS; it also permits the utilisation of the SO_2 evolved in many metallurgical operations. Its advantages are: it is easy and safe in its execution; the working-up of the tank-waste costs much less time and wages than hitherto; at least 90 to 95 per cent. of the sulphur contained in the waste are recovered, as against 50 to 60 per cent.; 80 per cent. of the total lime are recovered as calcium carbonate adapted for black-ash mixing. The $CaCl_2$ and $MgCl_2$ are all recovered except the unavoidable mechanical losses, which can be made very small; in any case they are as nothing compared with the saving in wages and in the muriatic acid required in the processes hitherto employed. If the requisite SO_2 is made from pyrites the production of sulphur can be increased by 50 per cent. over and above that recoverable from the waste. The ultimate residue only amounts to about 20 per cent. of the fresh waste, thus saving a great deal in carriage and depositing ground."

Some Results of the Study of Waste.

The question now arises, what result or advantage to the public will result from using any of these processes?

1st. It is clear that streams of yellow liquid giving out sulphuretted hydrogen may be converted into streams quite innocent, in a sanitary point of view, so far as the effect on the atmosphere is concerned.

A sub-question, however, arises, is it possible to apply the plan to streams containing very little sulphur unless at an unreasonable expense? On this point it may be considered enough to say that it is not well to begin our reforms with the most innocent, let us begin with the larger evils. It is certain that in many places small streams may be made to run together

and form a large one, and this may be treated as one. I am not, however, inclined to say that it is necessary to have any streams at all from the waste heaps. I may say, as already said, that if a well were dug in the middle of a heap the drainage would go into that well so long as it was properly pumped. The rainfall would go inwards, instead of outwards as at present, and the heap as well as its drainage would be innocent. There is no doubt of this, it is a certainty. Let us suppose cases where the heaps are large and the drainage great, as at St. Helens; we have only to use the method proposed, and we cease at once to allow any yellow liquid to flow into the river, but we obtain the sulphur in a profitable form. The manufacturers have imagined that they invented something valuable when they removed the acid from the brook at St. Helens, but the evil is only slightly diminished. The brook does not smell so badly, but it does smell, and as to appearance it is worse, whilst its effect on land cannot be much altered. This collective mode of treating the drainage from the waste will make the heaps give up some of their treasures.

In cases where this collective action is not required the same of course may be done by individuals; but in such cases, and, indeed, in all cases, the question arises, whether it would not be better to treat the tank waste beforehand and take out the sulphur before it reaches the heap. The various modes of doing this may be studied. I am not sure, of course, how far the newer plans are to be recommended, which have not been tried on a large scale, and none of the alkali makers have been pioneers of late, Mr. Chance excepted; but Mr. Mond's plans are well known, and they are now so well tried that proof is unnecessary.

But we know enough to say that, with all these facts together, there is no reason for allowing waste and drainage to be left to their natural and offensive decompositions.

This is perhaps scarcely the place to enter very fully on the plans for carrying out the new "Alkali, &c. Works Regulation Act," but so far as our streams are concerned it is necessary to speak of the subject here, and it may from this find its way to the alkali makers also.

It seems to be certain that no mode of laying down fresh tank waste has succeeded in avoiding offence. I must say, after abundant experience, that every method tried has been a decided failure. The offences have been twofold; one is by sending gases direct into the air, the other by sending solutions from the heaps, hurtful as solutions and ready themselves also to send sulphuretted hydrogen into the air.

Are there no exceptions to this rule? There may be practically; that is, there are a few places where the waste is laid in places not observed. These cases injure no one at present; it is not possible to say when they may cause injury. One cannot tell into what unlikely places men may take their habitations,

or what horrors may be caused by some day finding that houses had been built on waste from which there was no drainage, and which had remained long unoxidised. We have no right to spoil ground for our posterity; at least, if we have a legal right, it is not a humane act to exercise it.

But some of these places may be so situated that drainage comes from them; in which case oxidation goes on, and perfect innocence of ground will follow, such cases being common. The answer is, certainly this is true, but this drainage is an offensive sulphureous solution, and if it flows away must be objectionable; if it is retained it may remain long unchanged, as stated above. If it is allowed to flow, can it do so without being a nuisance? Such cases may exist, but they must be few.

Is the mode of covering heaps with soil not sufficient? I have never seen it done well, and on inquiry, I meet so many objections that I do not expect it to be done so well as to be a complete remedy for untreated waste.

It has been lately a favourite belief of alkali makers that the waste should be patted down; it was once a favourite belief that it should be put in small heaps; one is to prevent oxidation, the other to hasten it. But neither have been fully successful, judging by the senses or by any way. Covering would do very well, if it were done very completely. If no oxygen is allowed to enter, then combustion does not begin; and this result might be obtained by digging deep pits, and putting the waste into them, as has been done in some places. But in nearly all cases this would be too expensive. There are, however, cases in which considerable depth can be obtained without inordinate expense, and I have seen this used without offence. It is probable that a very small depth would be enough if the soil were immediately put over the waste, but it must be done at once; any delay in putting on the soil allows the heating to begin. Still, any mode of laying the soil without previous desulphurising renders a careful mode of drainage quite essential, unless in cases where the waste is thrown so deep that the drainage never reaches the surface. If well beaten down it is probable that it would lie in a deep pit for ages unaltered.

Unless in cases where the waste (or let us call it the sulphides of calcium, since it ought not to be *waste*) is put out of the reach of oxidation and drainage, we must make up our minds to let nature partially oxidize it, or we must do it ourselves. After oxidation the liquid must be treated to remove the sulphur. There is a choice; there is no monopoly of method; and more than one method pays at least its own expenses, and at times is said to do a great deal more.

I have objected to the mode of laying down the waste. It is not sufficient to pat it as usually done, simply because it is never done well enough to destroy its porosity. It is possible, perhaps. It is also, as said, possible to cover it over with earth sufficient to

keep out air, but it is not desired to keep out air so entirely that the stream from it is not partially oxidized and of a bright yellow. The monosulphide is very slightly soluble or coloured, and without oxidation we should have it permanent.

In one of my reports I have shown (the 14th + 15th Report, p. 41) that sulphide of calcium decomposes sulphate of lime, and intermediate products are formed. This is abundantly proved by the inquiries made. Now, it seems to me, but it is only a proposal, that it would be a possible way of applying this knowledge to mix up the old waste with the new at the time of laying it down. How much of each I do not know. The result would be, as I suppose, that the new waste would not heat so rapidly, because it would be exposed to cool surfaces. But it is probable that a part would oxidize nearly as rapidly, whilst the heat produced would be thrown out or dispersed at a lower temperature, because being dispersed throughout a greater mass. Next, the action of the sulphides would be to begin oxidizing themselves at the expense of the sulphates and sulphites, and thus there would be less air required or used for oxidation, whilst the oxidation which was caused by the oxygen salts would not produce heat, as there would be a simple interchange with no diminution of the volume of oxygen. I must add, that a trial made of this for me by Mr. Henry Brunner has not been successful.

It would be well to make a complete trial of this plan. It certainly would cause some expense, because the manipulation of the old waste would require to be paid for; it would be rough work, although probably less expensive than the present methods of oxidizing. However, the only real cure is to lay down no waste till the sulphur is removed, and to this we must rapidly come.

This report may be said to be chiefly on the VALUE OF OXYGEN in destroying putrefaction, in oxidizing impurities of nearly all kinds, and of course in preserving water and air from the unwholesome agencies to which they are exposed.

R. ANGUS SMITH.

August, 1881.

APPENDIX.

December 1881.

Having visited the works of Messrs. Schaffner and Helbig at Aussig, I may mention that I brought away a specimen of the waste after treatment there by Mond's process. The analysis gave—

Waste from Aussig.

Sulphur as Sulphide	-	0·09 %
Thiosulphate	-	3·64
Sulphite	-	0·72
Sulphate	-	0·84
		5·29

Total sulphur (direct oxidation) = 5·40 %.

Another Treatment of "Yellow Liquors."

When examining the action of steam and air I found that so much sulphur was oxidised that hyposulphite was formed. The plan was abandoned.

It was also found that with strong or hot solutions above 130°–140° F., the sulphur was dissolved when it was thrown down in the manganese process.

On p. 34 of my 14th and 15th combined report it is said:—

"This solubility of the sulphur applies also to strong solutions of caustic soda and potash, so that an attempt to precipitate from them will fail unless care is taken to pour them into a weak solution in which the manganese oxide is acting, and at such speed as to keep up a constant moderate strength.

"But the solubility may be taken advantage of in making hyposulphite of soda, because if a hot solution of caustic soda is used and an excess of sulphur, the sulphur will dissolve as soon as precipitated, and at every precipitation and solution some will be oxidised until the whole is converted into hyposulphite of soda.

"A similar experiment was tried with the waste itself so as to convert all its sulphide of calcium into hyposulphite, but the action was slow and unsatisfactory, the reason being in the insoluble character of the monosulphide. Still I think this might be made to succeed if it were desirable."

I had tried therefore hot solutions as well as aeration without manganese, but Mr. Dryden, at the works of Messrs. Chance, has

brought forward a plan which carries out Mond's process by using warmed solutions, and thus takes advantage of the formation of hyposulphites.

By partially oxidising the yellow solutions, and then adding hydrochloric acid, sulphur is thrown down. This is unquestionably a valuable process when acid can be had cheaply. I leave him to describe it in his own words. It is the latest phase of the sulphur process.

Messrs. Chance's Alkali Works, near Birmingham.

Treatment of Yellow Liquors to render them innocuous, and to recover the Sulphur contained in them.

The question of the best method of treating yellow liquors having become an urgent one, and hydrochloric acid being available for the purposes of such treatment, I naturally proposed neutralisation by this means, the collection of the precipitated sulphur by filtration, and the running off of the clear and innocuous filtrate. The large quantity of sulphuretted hydrogen evolved I proposed to burn, the resulting sulphurous acid to be carried into the chambers, arrangements for this process being already in existence in the works.

But it seemed to me that it would be much more satisfactory if the yellow liquor process could be made complete in itself, and to this end it became necessary to prevent the evolution of sulphuretted hydrogen gas, and to procure the whole of the sulphur in the solid form of a precipitate. This result was, of course, quite attainable if the liquor could be made to contain a quantity of hyposulphite of calcium in proportion to its sulphides, sufficient, on the addition of acid in slight excess, to bring about the reaction upon which Mond's process depends, that is, the complete precipitation of the sulphur.

Oxidation by means of a stream of air having in Mond's case when applied to moist vat waste brought about the result he desired, I proceeded to try the effect of passing a stream of air through the yellow liquor, but after continuing this experiment for a great many hours the desired end was not achieved. Moreover a considerable quantity of sulphuretted hydrogen was given off. This experiment was made with *cold* liquor and *cold* air.

I next proceeded to repeat the experiment, accompanying the stream of air with a jet of steam blown into the liquor, and I found that the liquor, being thus kept hot, had after several hours blowing and steaming assumed a condition which permitted the precipitation of its sulphur on addition of acid, without any evolution of sulphuretted hydrogen gas, and found too that the quantity of sulphuretted gas given off during the oxidation was so inappreciable as to be in no way offensive ; and, as to the constitution of the liquor before and after blowing, I found that two corresponding portions, tested for precipitable sulphur at the beginning and the end of the operation, gave one-fifth more in the latter case than in the former.

Experiments made with known quantities of acid gave a yield of sulphur at the rate of one ton sulphur for less than 50 cwt. of acid at 28° Tw.

The operations having been removed to their present site, a powerful Körting's blower was introduced, and the mixing of the liquor and the acid is now effected, after about three hours' blowing of the liquor, without the slightest trace of sulphuretted hydrogen being liberated; in fact the only escape from the mixing vessel is of quite another character, consisting of a little sulphurous acid arising from decomposition of hyposulphite, in excess of what is necessary for the reaction. This formation of excess of hyposulphite (by overblowing) is, indeed, the chief thing to be guarded against in the process, being followed, as I find, by the formation in the sulphur precipitate of an undue proportion of insoluble lime salts, one sample tested having contained as much as 13 per cent. of fixed residue. Ordinarily the proportion does not exceed 3, and has been as low as 0·75 per cent.

The batch, as soon as mixed, is run straight into wooden boxes lined with canvas, in which the sulphur is deposited, the chloride of calcium liquor draining off, and then passing through a tank containing crushed limestone, by which any free acid is neutralised, and thence into the canal.

I ought to mention that Messrs. Chance are making the only complete trials of Messrs. Helbig and Schaffner's process that I know of. The production of the sulphuretted hydrogen and its combustion are a complete success. As to the rest, I have not full results to record.

Supply of Sulphur.

I have in this report and on a former occasion spoken of digging deep wells in the mounds at St. Helens, and causing all the yellow drainage to run into them instead of into the rivers. I find that Messrs. Chance are treating a mound close to their works at Oldbury in this manner, and removing the sulphur from the yellow liquid obtained. This is the true method of relieving the streams, and preventing the evil arising from old waste heaps. New waste heaps may be treated much more effectually.

After considering all the methods now known, I see no reason why a very large amount of sulphur, which is wealth and power, ought not to be saved to the country. Enormous quantities of waste are thrown away daily. It is difficult to find room for the great masses, which are unsightly and for a long time unpleasant. They destroy land and every pleasant property of air, water, and landscape, besides causing illness in many cases. So useless is this matter held that it is taken out in steamboats built for the purpose, or dragged out in barges down the Tyne, to the ocean, where it is thrown out. The great sea does not allow us to observe the movements of the waste, but we do not know

if such a finely divided mass may not be easily driven on some part of the shore, affecting the harbour. At any rate it is an outcast product, and its 15 per cent. of sulphur is thrown away. We may say that all the sulphur used on the Tyne is thrown into the sea after it has done its first work, heedless of the fact that it cannot be destroyed, and is quite willing to do the same work again if it is only brought back to its original condition, or rescued from its bondage. This rescue certainly promises, and more than that it makes, profit.

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